

Network Systems
Science & Advanced
Computing
Biocomplexity Institute
& Initiative
University of Virginia

Estimation of COVID-19 Impact in Virginia

May 25th, 2022

(data current to May 21st – 24th)

Biocomplexity Institute Technical report: TR BI-2022-1532



BIOCOMPLEXITY INSTITUTE

biocomplexity.virginia.edu

About Us

- Biocomplexity Institute at the University of Virginia
 - Using big data and simulations to understand massively interactive systems and solve societal problems
- Over 20 years of crafting and analyzing infectious disease models
 - Pandemic response for Influenza, Ebola, Zika, and others



Points of Contact

Bryan Lewis
brylew@virginia.edu

Srini Venkatramanan
srini@virginia.edu

Madhav Marathe
marathe@virginia.edu

Chris Barrett
ChrisBarrett@virginia.edu

Model Development, Outbreak Analytics, and Delivery Team

Przemyslaw Porebski, Joseph Outten, Brian Klahn, Alex Telionis,
Srinivasan Venkatramanan, Bryan Lewis,

Aniruddha Adiga, Hannah Baek, Chris Barrett, Jiangzhuo Chen, Patrick Corbett,
Stephen Eubank, Galen Harrison, Ben Hurt, Dustin Machi, Achla Marathe,
Madhav Marathe, Mark Orr, Akhil Peddireddy, Erin Raymond, James Schlitt, Anil Vullikanti,
Lijing Wang, James Walke, Andrew Warren, Amanda Wilson, Dawen Xie



Overview

- **Goal:** Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
 - Calibrate explanatory mechanistic model to observed cases
 - Project based on scenarios for next 4 months
 - Consider a range of possible mitigation effects in "what-if" scenarios
- **Outcomes:**
 - Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
 - Geographic spread over time, case counts, healthcare burdens

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.

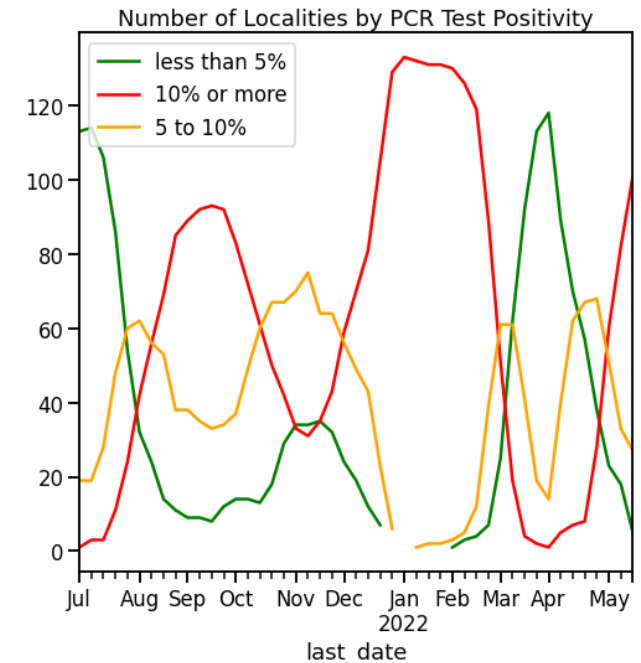
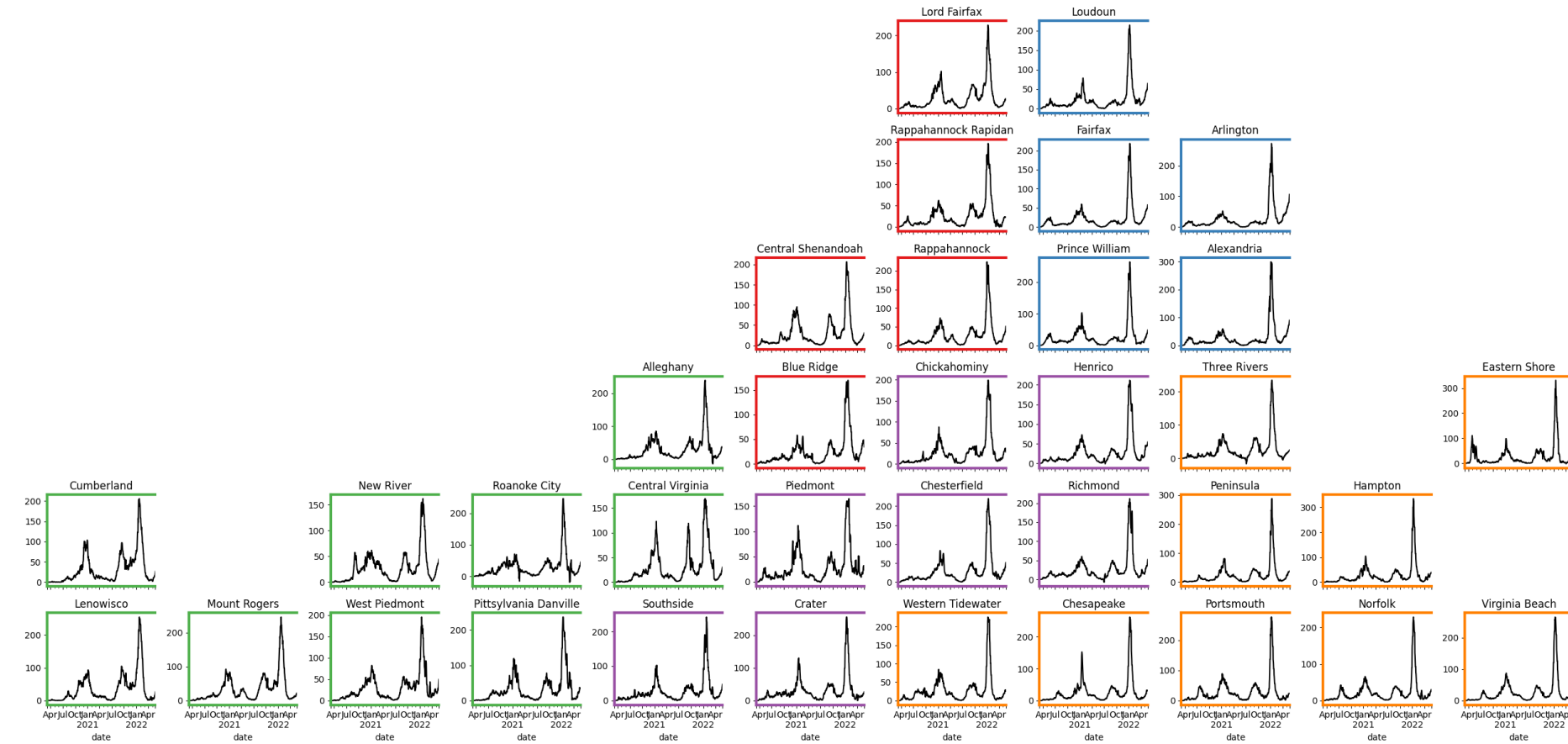
Even without perfect projections, we can confidently draw conclusions:

- **Case rates continue to rise as do hospitalizations**
- VA 7-day mean daily case rate increased to 39/100K from 32/100K
 - US seems to be entering a plateau, down slightly to 33/100K from 36/100K
 - VA hospital occupancy (rolling 7 day mean of 441) has steadily rising for over a month
- Projections anticipate future growth in cases, with potential for growth to continue for several weeks:
 - VA continues to tracked BA.2.12.1 scenario from April 23rd projections closely
 - Rise in hospitalizations tracking cases pretty closely for past uncertainty surrounds impact of weather and changing social interactions
- Model updates:
 - Speculative BA.4 scenario added though parameterization contains a lot of uncertainty
 - Adaptive scenario BA.2.12.1 scenario to capture the future growth of this more transmissible variant
 - Models need to change their focused outcome to hospitalization or aggregate counties to districts to minimize noisy fluctuations

The situation continues to change. Models continue to be updated regularly.

Situation Assessment

Case Rates (per 100k) and Test Positivity



County level RT-PCR test positivity

Green: <5.0% (or <20 tests in past 14 days)
Orange: 5.0%-10.0% (or <500 tests and <2000 tests/100k and >10% positivity over 14 days)
Red: >10.0% (and not "Green" or "Yellow")

District Trajectories

Goal: Define epochs of a Health District's COVID-19 incidence to characterize the current trajectory

Method: Find recent peak and use hockey stick fit to find inflection point afterwards, then use this period's slope to define the trajectory

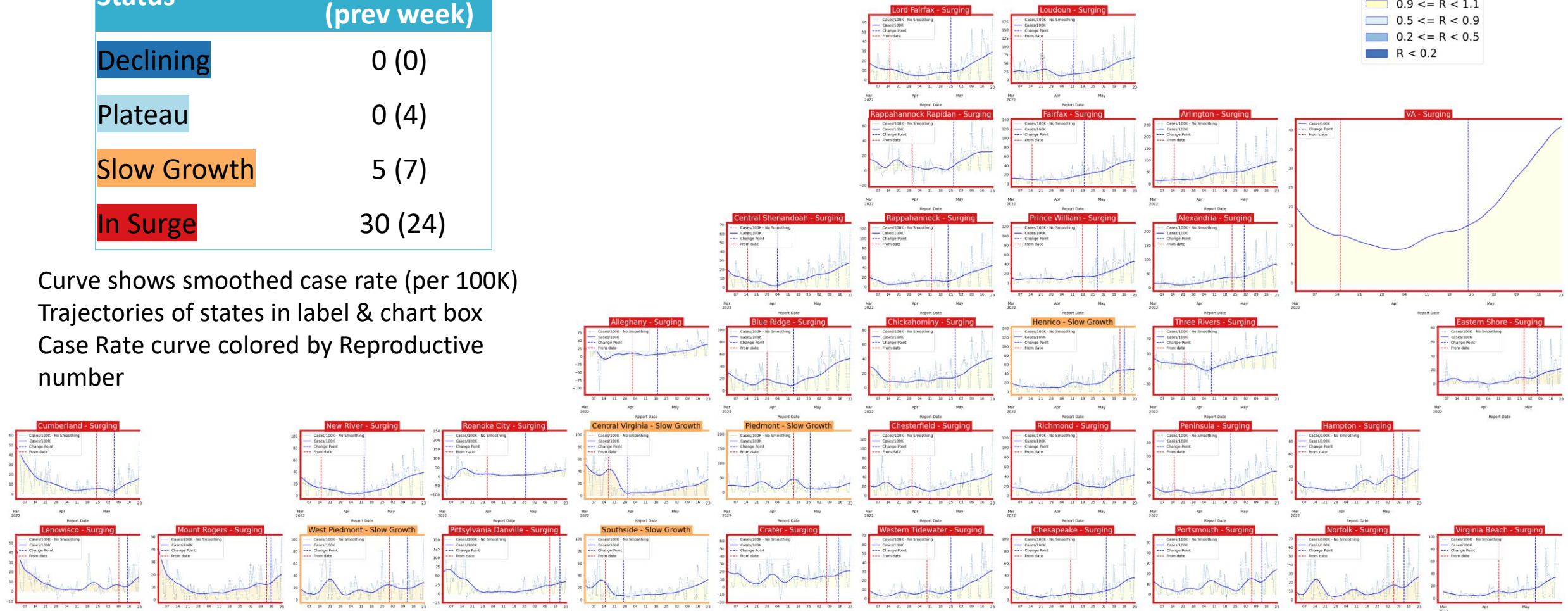
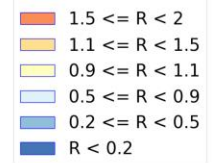


Trajectory	Description	Weekly Case Rate (per 100K) bounds
Declining	Sustained decreases following a recent peak	below -0.9
Plateau	Steady level with minimal trend up or down	above -0.9 and below 0.5
Slow Growth	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5
In Surge	Currently experiencing sustained rapid and significant growth	2.5 or greater

District Trajectories – last 10 weeks

Status	# Districts (prev week)
Declining	0 (0)
Plateau	0 (4)
Slow Growth	5 (7)
In Surge	30 (24)

Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive
number



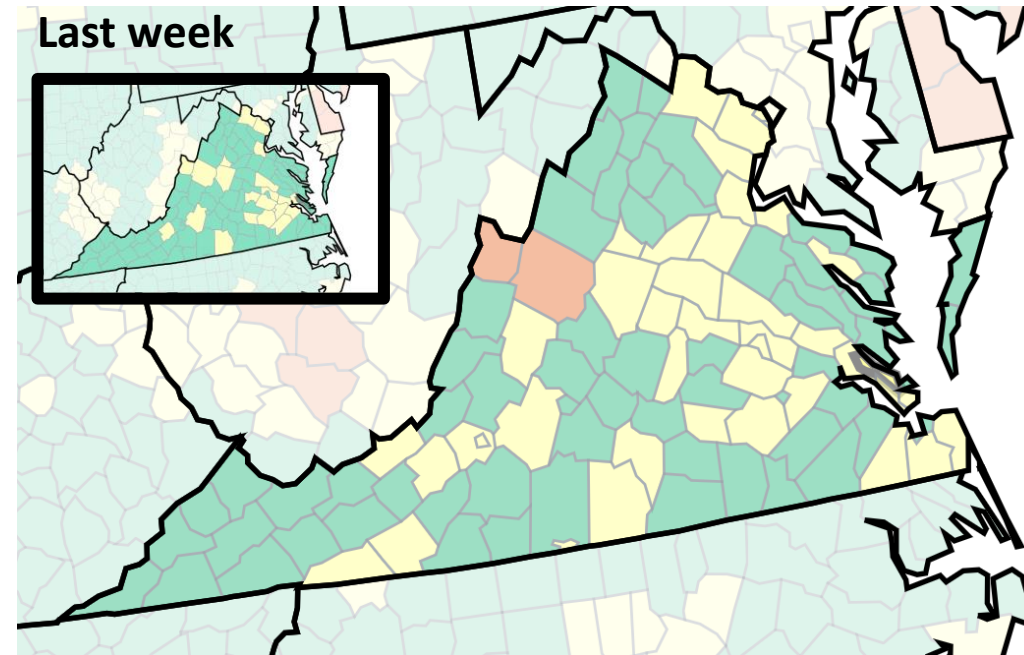
CDC's new COVID-19 Community Levels

What Prevention Steps Should You Take Based on Your COVID-19 Community Level?

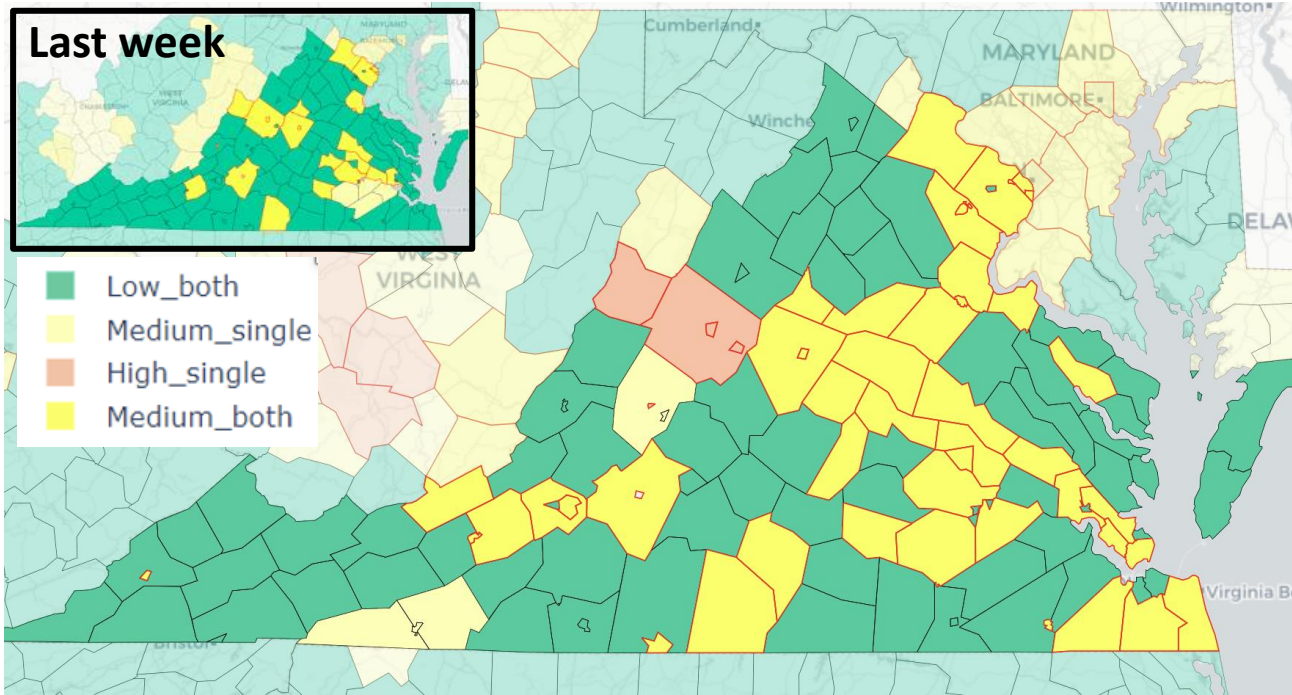
Low	Medium	High
<ul style="list-style-type: none"> Stay up to date with COVID-19 vaccines Get tested if you have symptoms 	<ul style="list-style-type: none"> If you are at high risk for severe illness, talk to your healthcare provider about whether you need to wear a mask and take other precautions Stay up to date with COVID-19 vaccines Get tested if you have symptoms 	<ul style="list-style-type: none"> Wear a mask indoors in public Stay up to date with COVID-19 vaccines Get tested if you have symptoms Additional precautions may be needed for people at high risk for severe illness
People may choose to mask at any time. People with symptoms, a positive test, or exposure to someone with COVID-19 should wear a mask.		

COVID-19 Community Levels – Use the Highest Level that Applies to Your Community				
New COVID-19 Cases Per 100,000 people in the past 7 days	Indicators	Low	Medium	High
Fewer than 200	New COVID-19 admissions per 100,000 population (7-day total)	<10.0	10.0-19.9	≥20.0
	Percent of staffed inpatient beds occupied by COVID-19 patients (7-day average)	<10.0%	10.0-14.9%	≥15.0%
200 or more	New COVID-19 admissions per 100,000 population (7-day total)	NA	<10.0	≥10.0
	Percent of staffed inpatient beds occupied by COVID-19 patients (7-day average)	NA	<10.0%	≥10.0%

The COVID-19 community level is determined by the higher of the new admissions and inpatient beds metrics, based on the current level of new cases per 100,000 population in the past 7 days



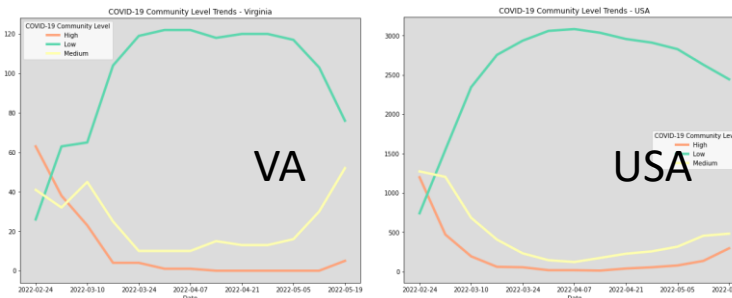
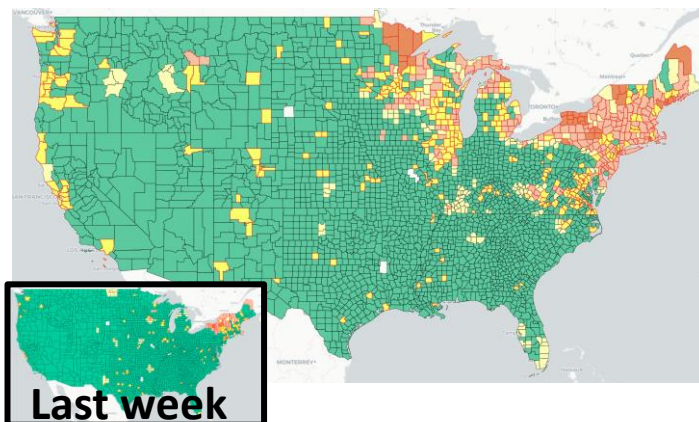
CDC's new COVID-19 Community Levels



Red outline indicates county had 200 or more cases per 100k in last week

Pale color indicates either beds or occupancy set the level for this county

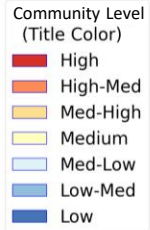
Dark color indicates both beds and occupancy set the level for this county



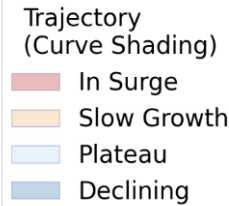
COVID-19 Community Levels – Use the Highest Level that Applies to Your Community				
New COVID-19 Cases Per 100,000 people in the past 7 days	Indicators	Low	Medium	High
Fewer than 200	New COVID-19 admissions per 100,000 population (7-day total)	<10.0	10.0-19.9	≥20.0
	Percent of staffed inpatient beds occupied by COVID-19 patients (7-day average)	<10.0%	10.0-14.9%	≥15.0%
200 or more	New COVID-19 admissions per 100,000 population (7-day total)	NA	<10.0	≥10.0
	Percent of staffed inpatient beds occupied by COVID-19 patients (7-day average)	NA	<10.0%	≥10.0%

The COVID-19 community level is determined by the higher of the new admissions and inpatient beds metrics, based on the current level of new cases per 100,000 population in the past 7 days

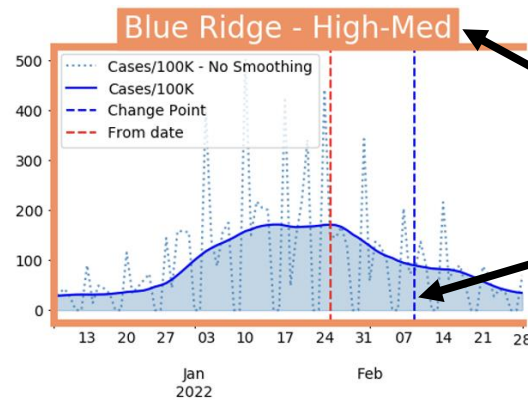
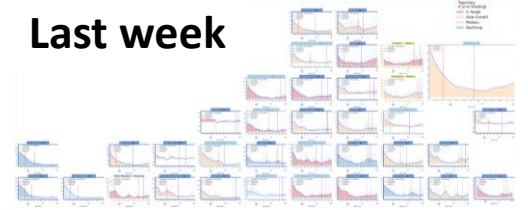
District Trajectories with Community Levels



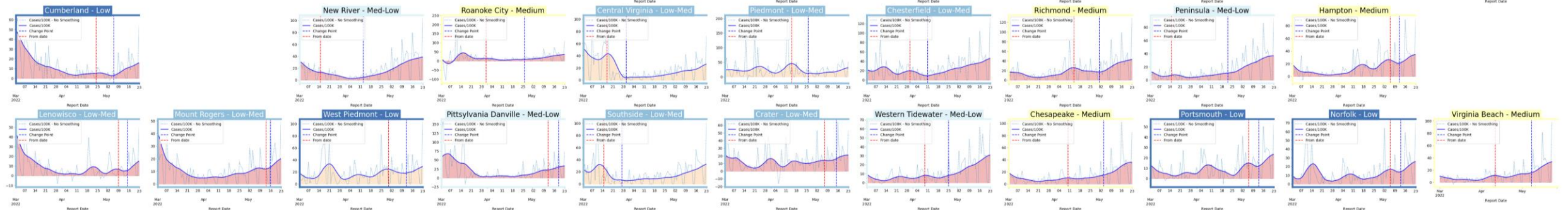
Curve shows smoothed case rate (per 100K)
 CDC's new [Community Level](#) aggregated to district level in label & chart box color
 Case Rate curve colored by Trajectory



Last week



District's Aggregate
Community Level
 Aggregate level a simple mean
of all levels for counties in district
 Case rate
Trajectory



Estimating Daily Reproductive Number – Redistributed gap

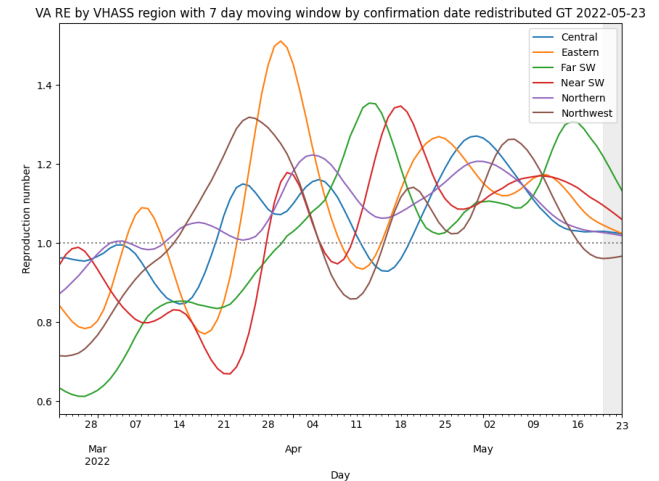
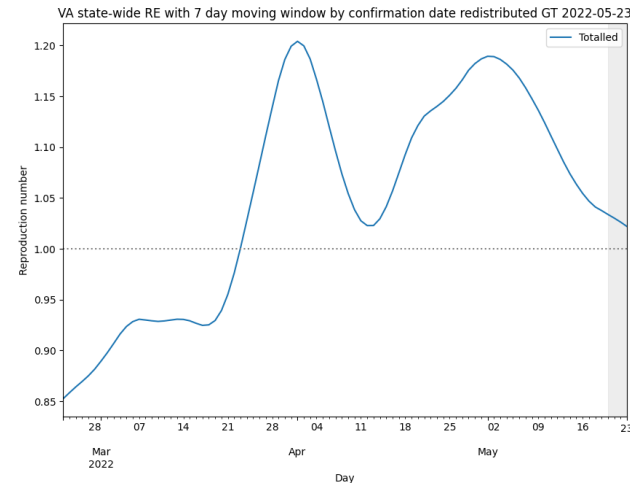
May 23rd Estimates

Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	1.022	-0.089
Central	1.023	-0.072
Eastern	1.024	-0.066
Far SW	1.133	0.106
Near SW	1.060	-0.064
Northern	1.019	-0.096
Northwest	0.967	-0.189

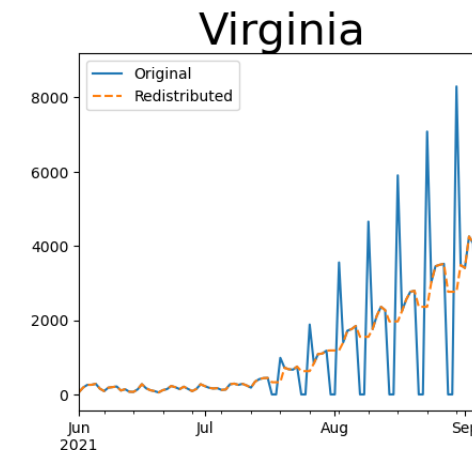
Methodology

- Wallinga-Teunis method (EpiEstim¹) for cases by confirmation date
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, <https://doi.org/10.1093/aje/kwt133>



Skipping Weekend Reports & holidays biases estimates
Redistributed “big” report day to fill in gaps, and then estimate R from “smoothed” time series

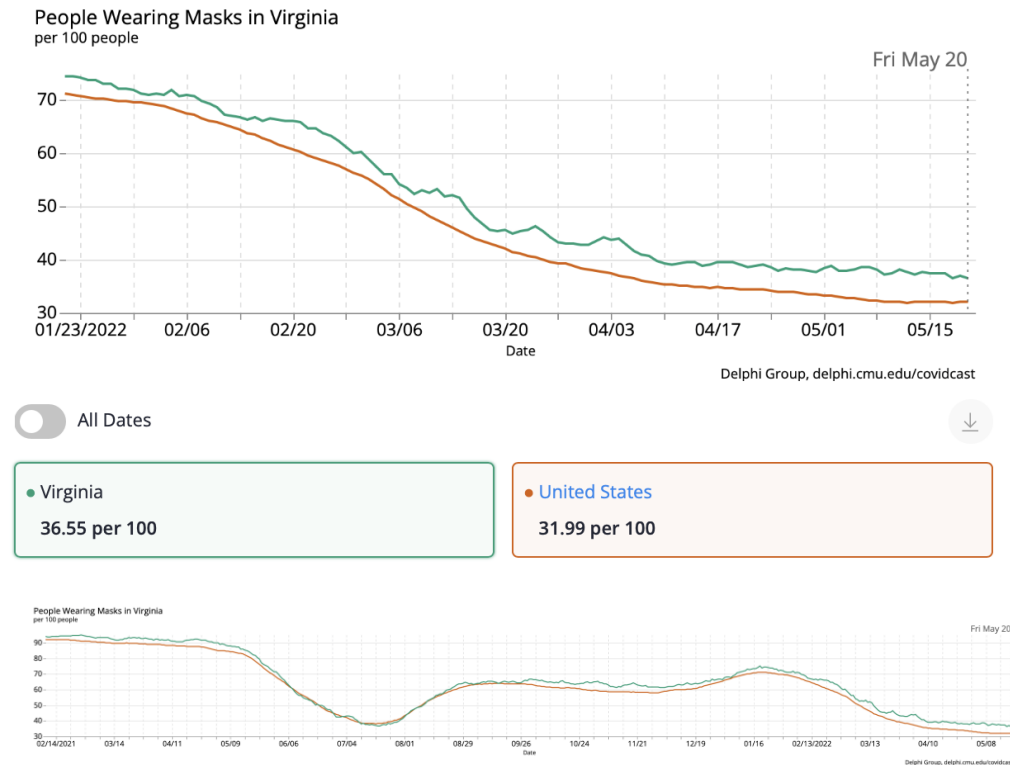


Mask Usage and Vaccination

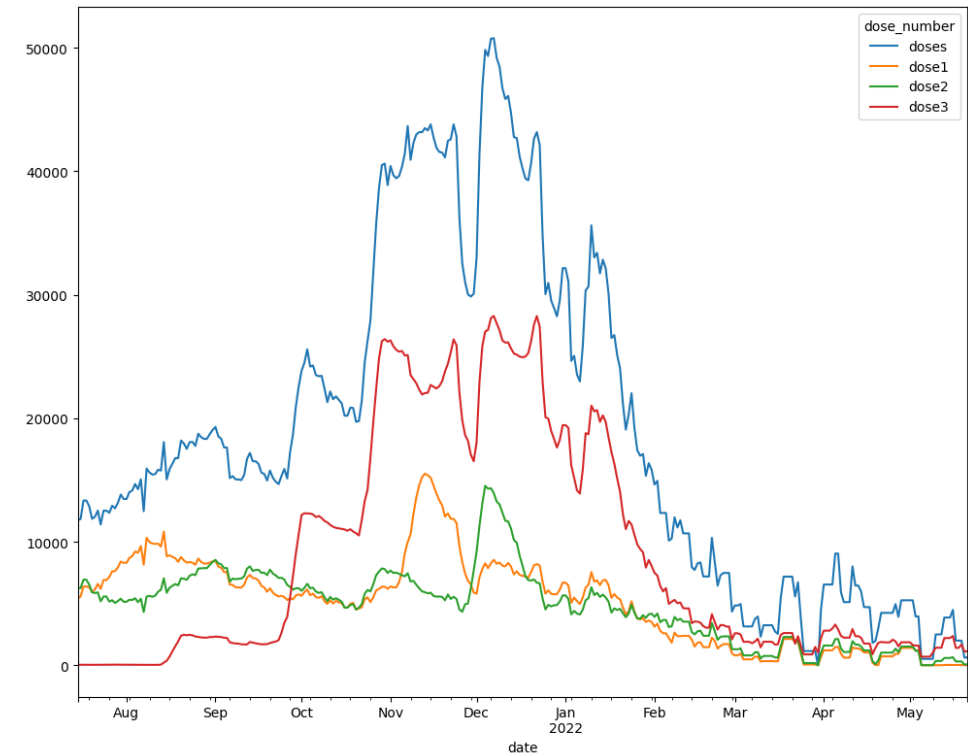
Self-reported mask usage continues to fall

- US and VA experienced similar decreases
- Vaccination has leveled off and has leveled off after a slight rise in early April

PEOPLE WEARING MASKS CHART



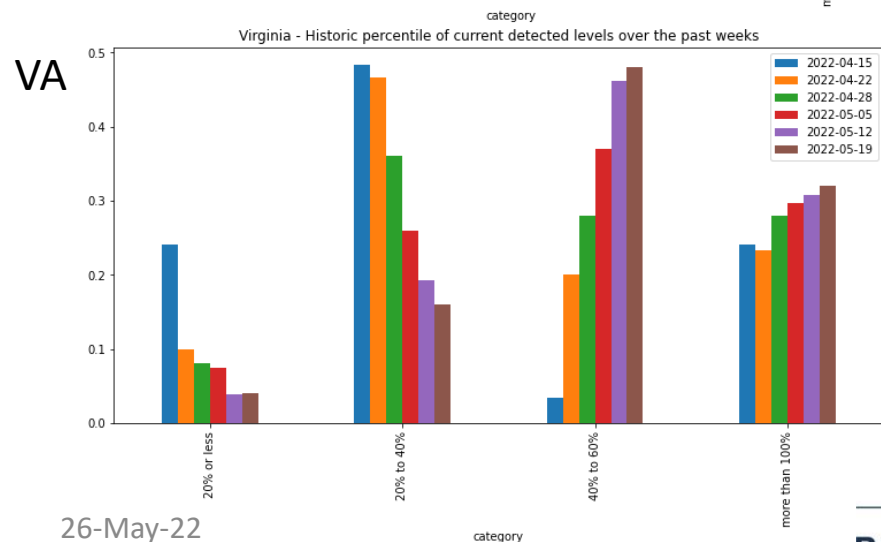
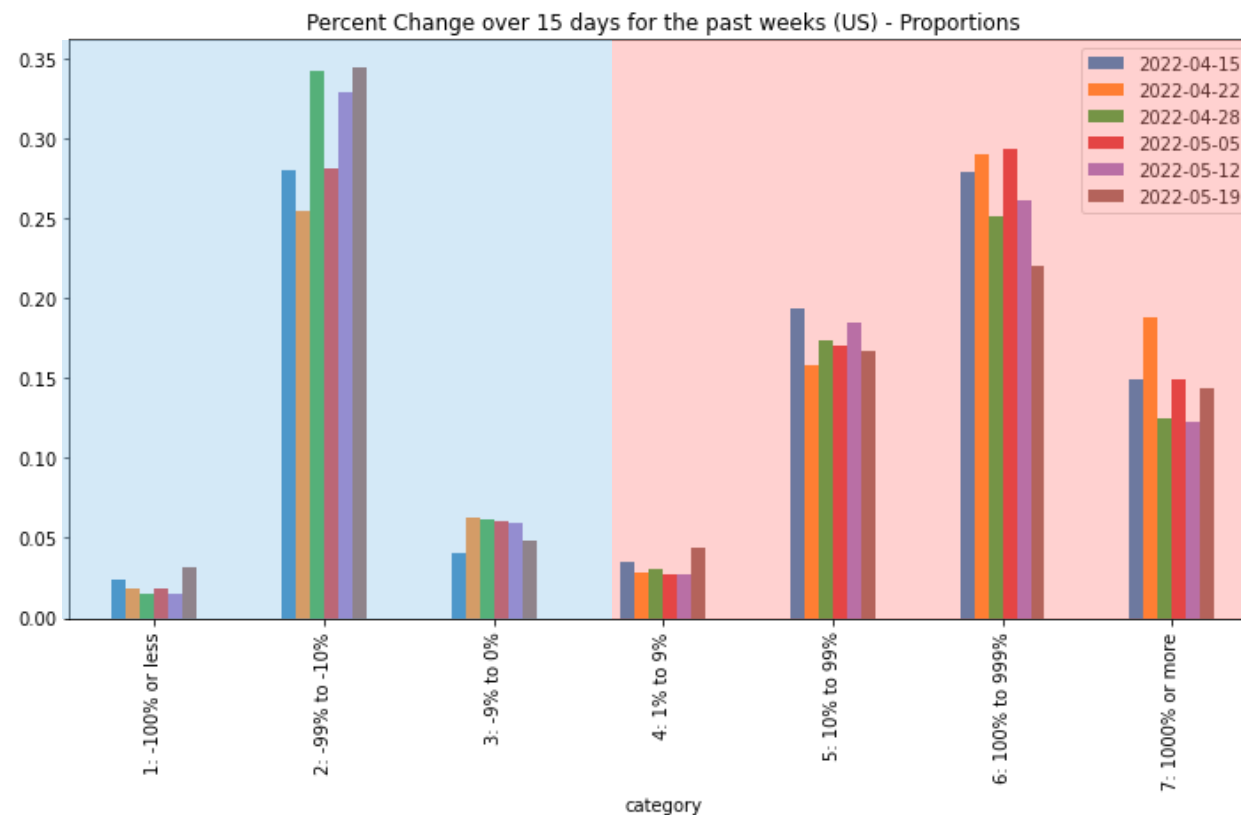
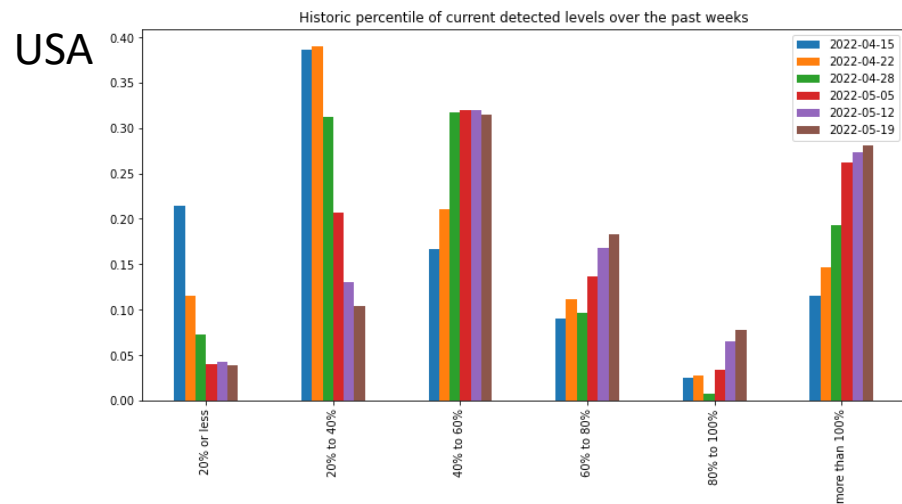
All Doses - Daily



Wastewater Monitoring

Wastewater provides a coarse early warning of COVID-19 levels in communities

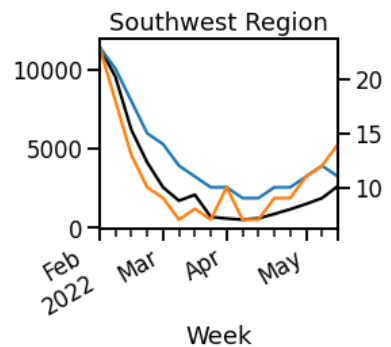
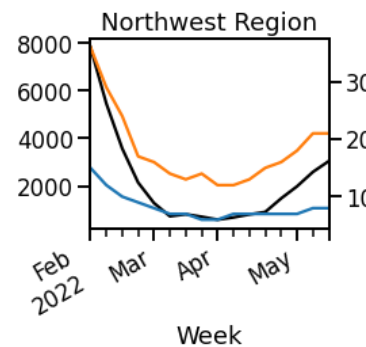
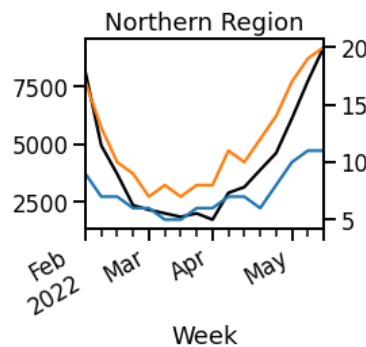
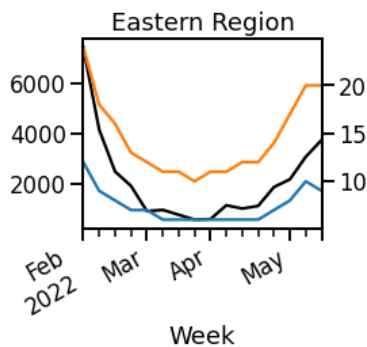
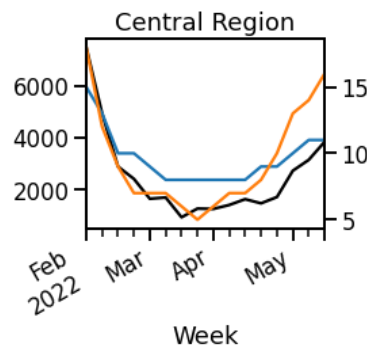
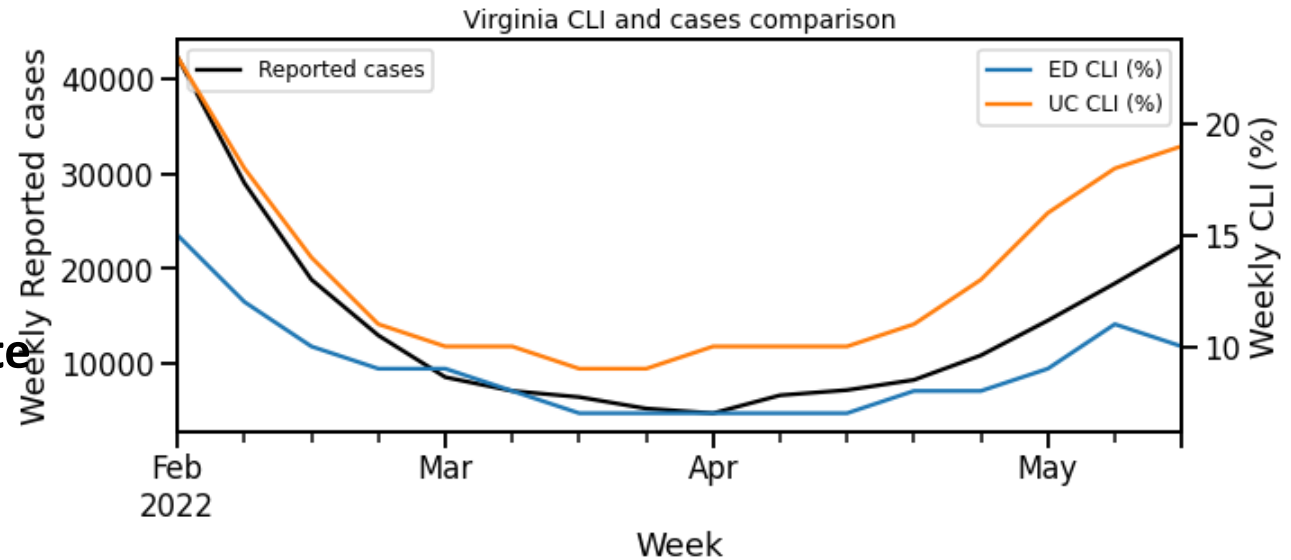
- Overall in the US, there is an increase in sites with increased levels of virus compared to 15 days ago, however the pace of growth slows
- Current virus levels are at or exceeding max of previous historical levels, has slowed, though more sites are entering upper quintiles



COVID-like Illness Activity

COVID-like Illness (CLI) gives a measure of COVID transmission in the community

- Emergency Dept (ED) based CLI is more correlated with case reporting
- Urgent Care (UC) is a leading indicator but prone to some false positives
- **Current trends in UC CLI are rising, but the rate of increase is slowing**

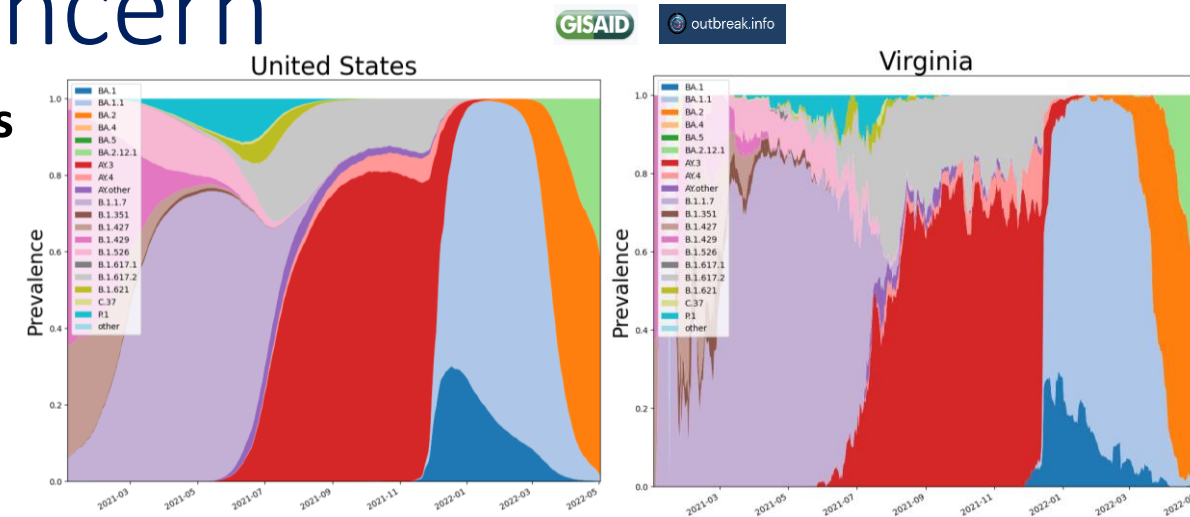


SARS-CoV2 Variants of Concern

Emerging new variants will alter the future trajectories of pandemic and have implications for future control

- Emerging variants can:
 - Increase transmissibility
 - Increase severity (more hospitalizations and/or deaths)
 - Limit immunity provided by prior infection and vaccinations
- Genomic surveillance remains very limited
 - Challenges ability to estimate impact in US to date and estimation of arrival and potential impact in future

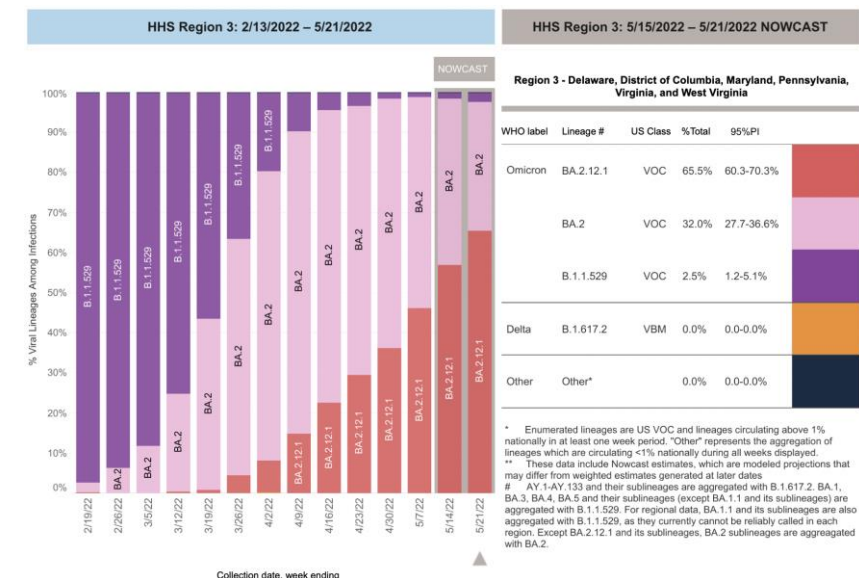
WHO label	Pango lineage*	GISAID clade	Nextstrain clade	Additional amino acid changes monitored*	Earliest documented samples	Date of designation
Alpha	B.1.1.7	GRY	20I (V1)	+S:484K +S:452R	United Kingdom, Sep-2020	18-Dec-2020
Beta	B.1.351	GH/501Y.V2	20H (V2)	+S:L18F	South Africa, May-2020	18-Dec-2020
Gamma	P.1	GR/501Y.V3	20J (V3)	+S:681H	Brazil, Nov-2020	11-Jan-2021
Delta	B.1.617.2	GI/478K.V1	21A, 21I, 21J	+S:417N +S:484K	India, Oct-2020	VOI: 4-Apr-2021 VOC: 11-May-2021
Omicron*	B.1.1.529	GRA	21K, 21L	+R346K	Multiple countries, Nov-2021	VUM: 24-Nov-2021 VOC: 26-Nov-2021



Omicron Prevalences subvariant BA.2 dominates

CDC nowcast for week ending May 21st in Region 3 with BA 2.12.1 at 66% (last week 57%)

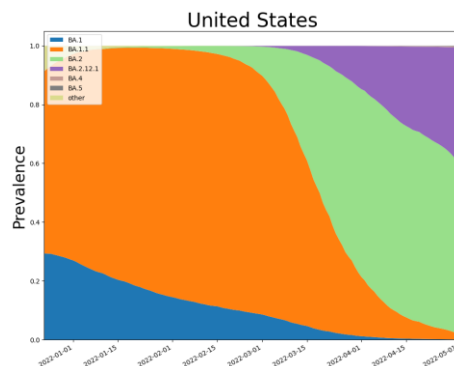
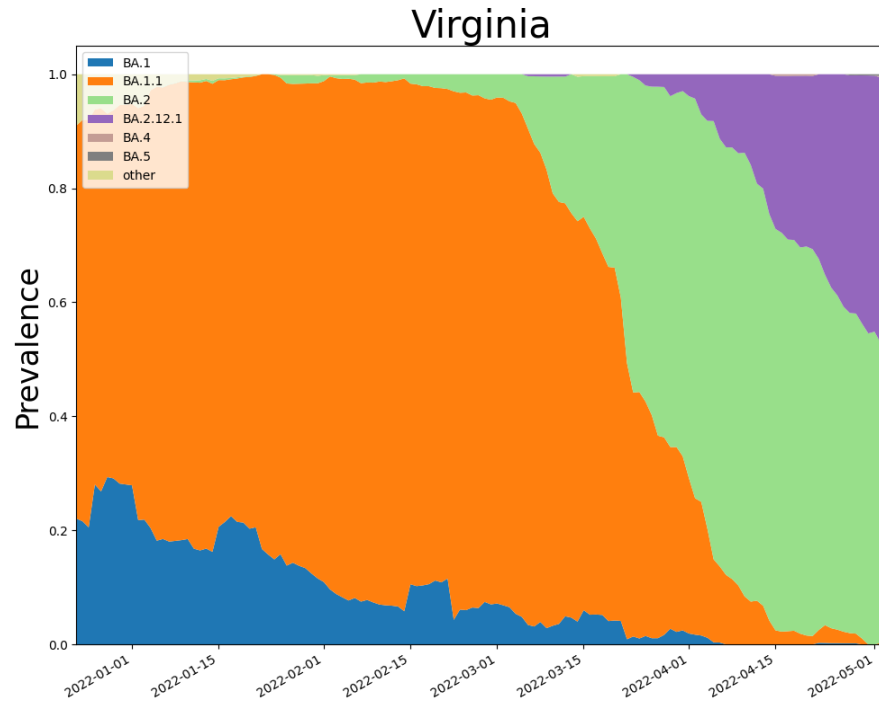
Overall BA.2.12.1 in USA now at 58% (last week 49%)



Collection date, week ending

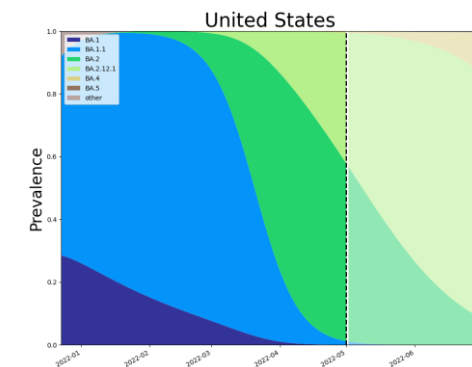
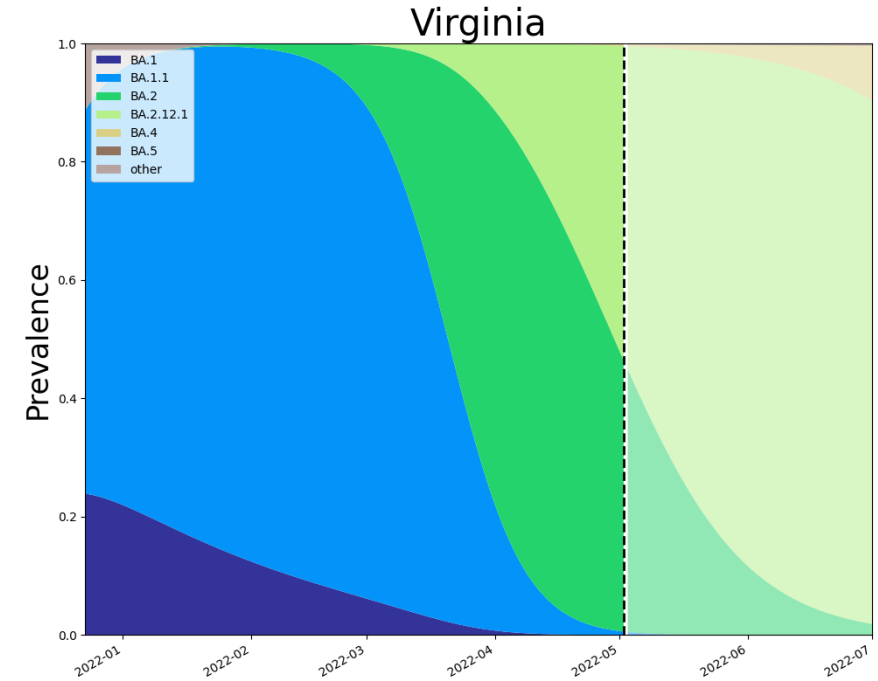
SARS-CoV2 Omicron and Sub-Variants

As detected in whole Genomes in public repositories



26-May-22

VoC Polynomial Fit Projections

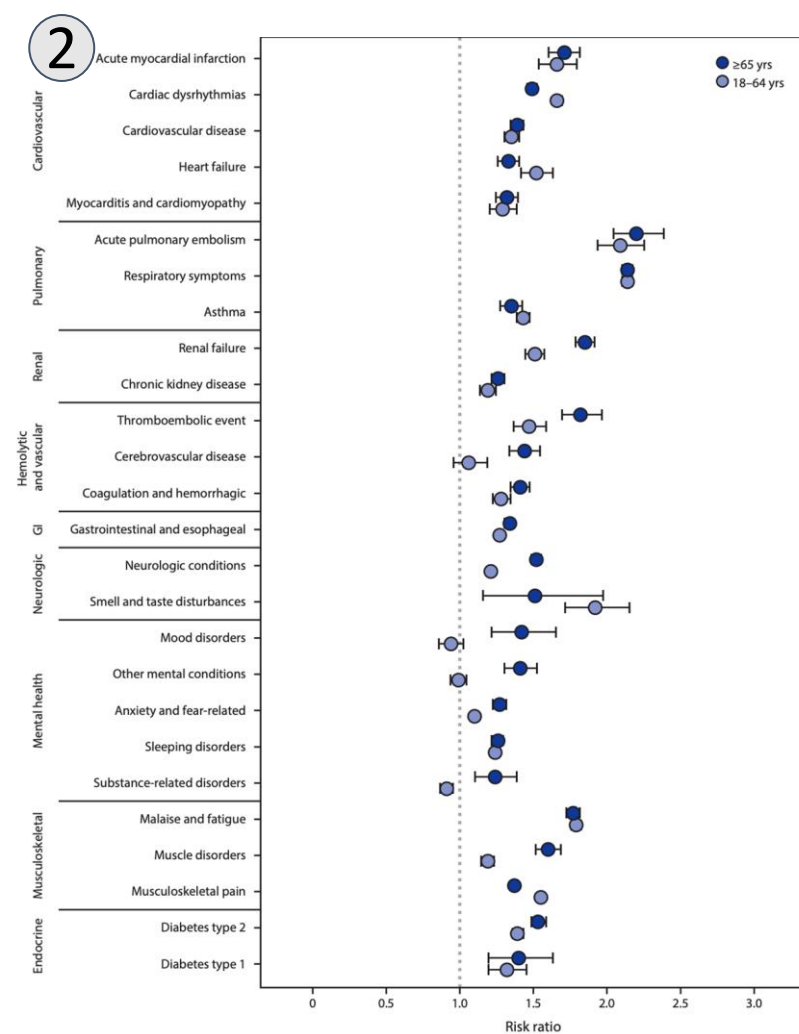
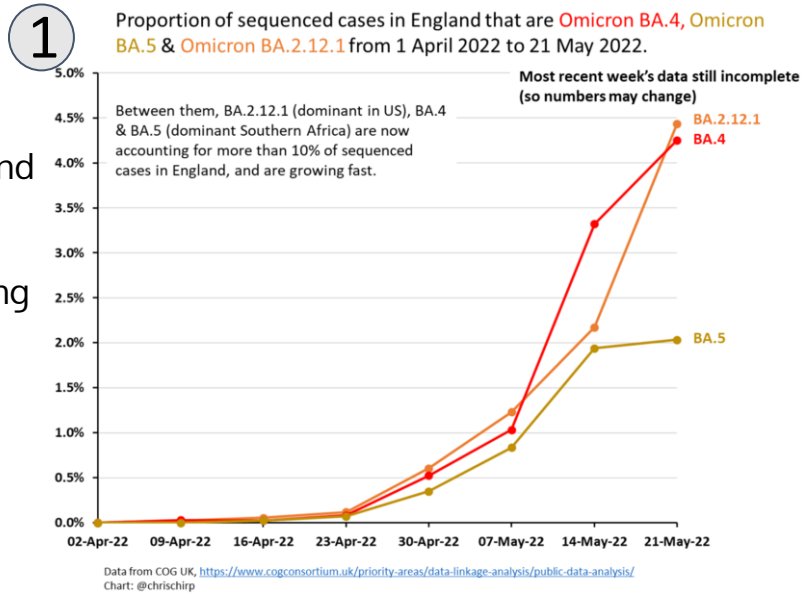


Note: Data lags force projections to start in past. Everything from dotted line forward is a projection.



Pandemic Pubs

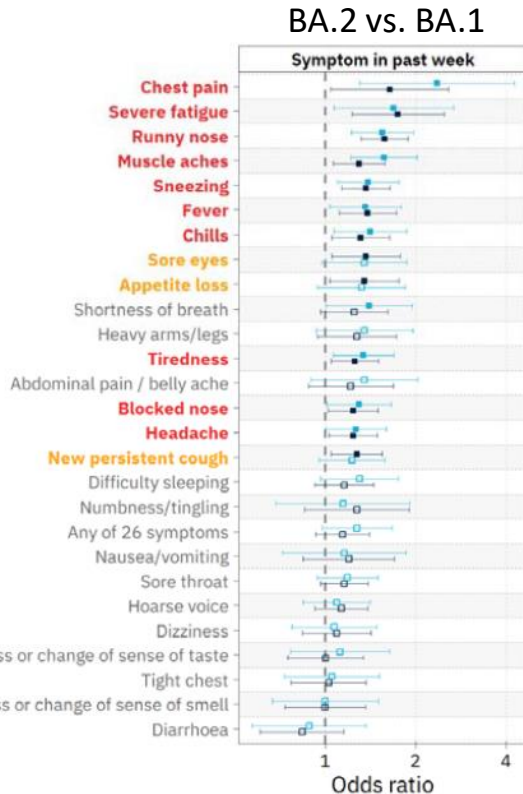
1. UK currently experiencing equal proportions BA.4 and BA.2.12.1. They are predicted to dominate circulating strains by early June.
2. COVID-19 survivors have twice the risk for developing pulmonary embolism or respiratory conditions
3. Quebec: 33.5% of individuals infected in the week ending May 12-17, 2022 had had COVID-19 previously. For 40% of these cases, the 1st infection occurred between December 2021 and February 2022.
4. Omicron BA.2 associated with reporting more symptoms, with greater disruption to daily activities, than BA.1



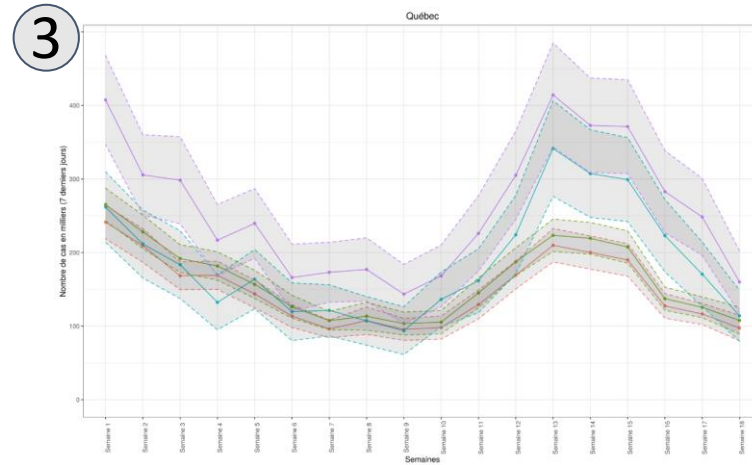
4

Imperial College London: among random samples of the population in England from 1 May 2020 to 31 March 2022. Changing symptom profiles associated with the different variants over that period, with lower reporting of loss of sense of smell and taste for Omicron compared to previous variants, and higher reporting of cold-like and influenza-like symptoms, controlling for vaccination status.

<https://www.medrxiv.org/content/10.1101/2022.05.21.22275368v1>



Within a background of decreasing cases, there is currently a VoC shift from BA.2 to other lineages of Omicron.
<https://twitter.com/chrischirp/status/1528723315665272832>



The CIRANO institute published a recent report estimating the incidence of COVID-19 cases in Quebec. As part of this report reinfection estimates resolve to between 4700 and 7700 reinfections a day, of which 1900 to 3000 a day had covid between Dec 21 and April 22.

https://twitter.com/lisa_iannattone/status/1527829419645095936?s=12&t=eMO1VoldWe5rS9HduhckYw

<https://www.cirano.qc.ca/en/news/1081>

Researchers at the CDC conducted a retrospective matched cohort study to analyze EHRs during March 2020–November 2021, from Cerner Real-World Data,* a national, deidentified data set of approximately 63.4 million unique adult records from 110 data contributors in the 50 states, **found one in five COVID-19 survivors aged 18–64 years and one in four survivors aged ≥65 years experienced at least one incident condition that might be attributable to previous COVID-19.**

https://www.cdc.gov/mmwr/volumes/71/wr/mm7121e1.htm?s_cid=mm7121e1_w#contribAff

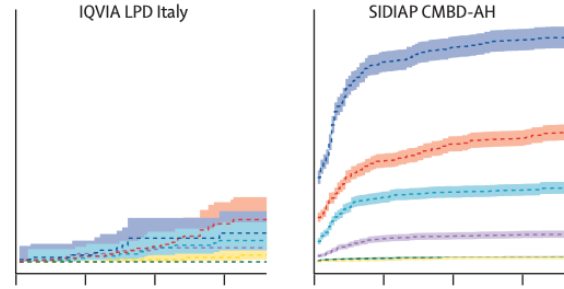
Pandemic Pubs (last week)

1. New data gives estimates on the degree of protection from post-acute sequelae PASC offered by vaccines.
2. European study gives baseline risk of 1% of venous or arterial thromboembolism among COVID patients. Increases among males, hospitalizations and the elderly.
3. ECDC list BA.4 and BA.5 as VoCs. Cases appear to have peaked in S. Africa with low severe outcomes.
4. UK: Bank of England's Monetary Policy Committee reports concern that share of the 16-64 y/o population who are outside the workforce and do not seeking a job because of long-term sickness is a record high.

1 Table 2. Post-Acute Sequelae of Sars-Cov-2 (PASC) Mortality and Morbidity Risk at 28 days: vaccine vs. no-vaccine.

Outcomes	Total (n)	28 day risk (Rates per 1,000)		Relative Risk (95% CIs)	Attributable Risk (95% CIs)
		Vaccine + COVID	No-Vaccine + COVID		
Mortality	50450	171 (6.78)	522 (20.69)	0.33 (0.28, 0.39)	-13.91 (-15.94, -11.89)
New Conditions since COVID					
Hypertension	25862	176 (13.52)	384 (29.90)	0.45 (0.38, 0.54)	-16.38 (-19.93, -12.83)
Diabetes mellitus	38762	116 (5.98)	269 (13.88)	0.43 (0.35, 0.54)	-7.90 (-9.87, -5.93)
Thyroid Disease	43481	82 (3.80)	193 (8.80)	0.43 (0.33, 0.56)	-5.00 (-6.48, -3.51)
Heart Disease	33836	253 (15.41)	543 (31.17)	0.49 (0.43, 0.57)	-15.76 (-18.96, 12.57)
Malignant Neoplasms	42705	84 (3.95)	260 (12.14)	0.32 (0.25, 0.42)	-8.20 (-9.89, -6.50)
Thrombosis	43486	137 (6.36)	332 (15.14)	0.42 (0.34, 0.51)	-8.78 (-10.72, -6.85)
Rheumatoid Arthritis	49289	16 (0.65)	32 (1.30)	0.50 (0.28, 0.91)	-0.65 (-1.20, -0.09)
Mental Disorders	32307	231 (14.77)	604 (36.23)	0.41 (0.35, 0.47)	-21.45 (-24.86, -18.05)
New Symptoms since COVID					
Respiratory Symptoms	50450	2263 (89.71)	3219 (127.61)	0.70 (0.67, 0.74)	-37.90 (-43.32, -32.48)
Headache	50450	450 (17.84)	804 (31.87)	0.56 (0.50, 0.63)	-14.03 (-16.75, -11.32)
Fatigue	50450	1138 (45.14)	1750 (69.38)	0.65 (0.61, 0.70)	-24.26 (-28.31, -20.21)
Body Ache	50450	235 (9.32)	480 (19.03)	0.50 (0.42, 0.57)	-9.71 (-11.77, -7.65)
Diarrhea or constipation	50450	857 (33.97)	1424 (56.45)	0.60 (0.55, 0.65)	-22.48 (-26.10, -18.86)

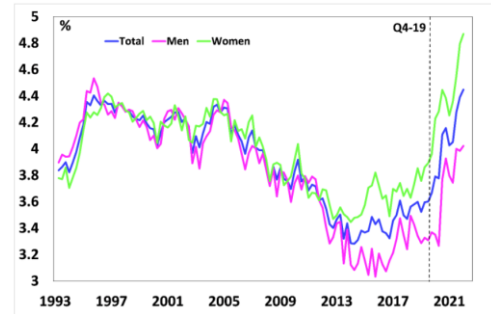
2



A distributed network cohort study using primary care records from the Netherlands, Italy, Spain, and the UK, and outpatient specialist records from Germany. Overall, 909 473 COVID-19 cases and 32329 patients hospitalised with COVID-19 on or after Sept 1, 2020, were studied. Cumulative 90-day incidence of venous thromboembolism ranged from 0.2% to 0.8% among COVID-19 cases, and up to 4.5% for those hospitalised. The occurrence of venous thromboembolism in patients with COVID-19 was associated with an increased risk of death (adjusted HRs 4.42 [3.07–6.36] for those not hospitalised and 1.63 [1.39–1.90] for those hospitalised), as was the occurrence of arterial thromboembolism (3.16 [2.65–3.75] and 1.93 [1.57–2.37]).
[https://www.thelancet.com/journals/laninf/article/PIIS1473-3099\(22\)00223-7/fulltext](https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(22)00223-7/fulltext)

4

Figure 6. UK – Per cent of Adult Population Aged 16-64 Who Are Outside the Workforce and Do Not Want a Job Because of Long-term Sickness

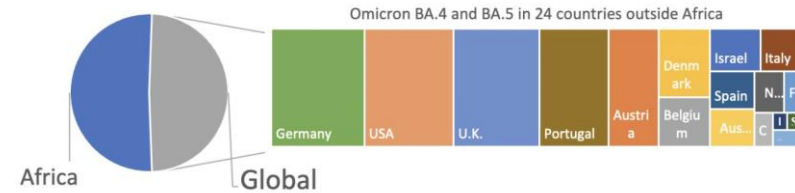


Patients with confirmed COVID-19 diagnosis, minimum age of 18 years with 3 month follow-up post-diagnosis between September 21, 2020 and December 14, 2021 were identified from TriNetX research network platform. 1,578,719 patients with confirmed COVID-19 were identified and 1.6% (n=25,225) completed vaccination. Before matching vaccinated individuals who were found to be positive tended to be older and have more comorbidities.

<https://academic.oup.com/ofid/advance-article/doi/10.1093/ofid/ofac228/6582238?login=false&Yn2vXtn7Cpg.t>
<https://twitter.com/Tuliodna/status/1526470866762141697>

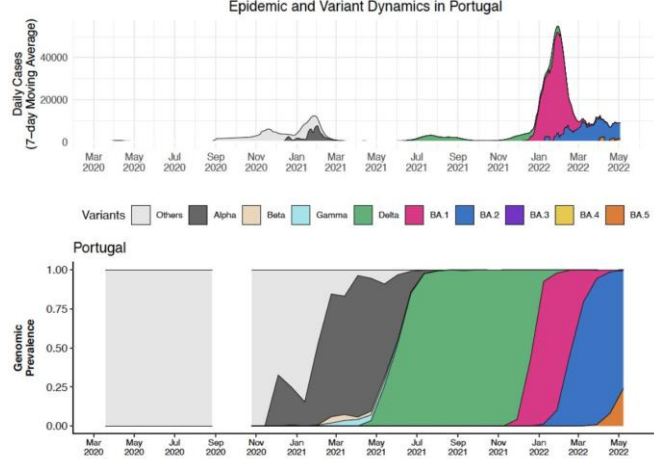
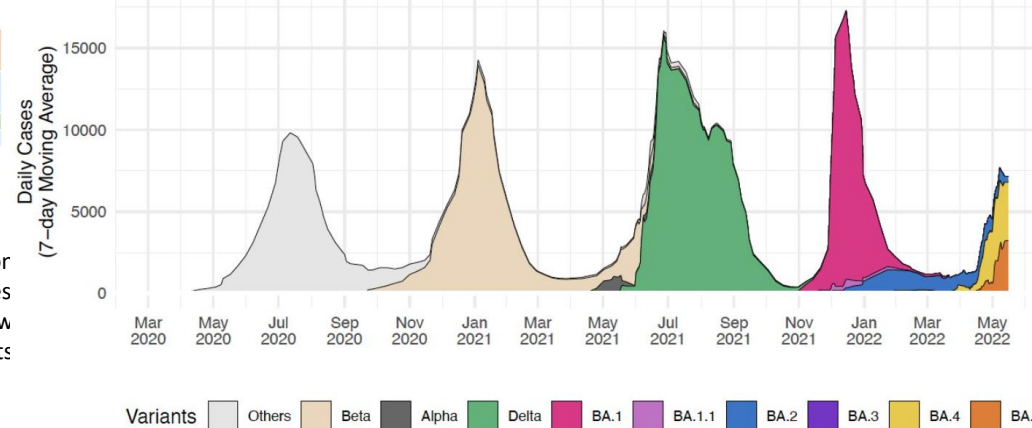
3

Omicron BA.4 & BA.5 (>2,000 genomes - 13 May 2022)



Tulio de Oliveira Director of CERi (Centre for Epidemic Response & Innovation S.Africa) reports BA.4 and BA.5 have significantly increased cases in countries with strong BA.1 but minimal BA.2 waves, S. Africa and Portugal. Locations with similar conditions could be more vulnerable to these immune escape variants
<https://twitter.com/Tuliodna/status/1526470866762141697>

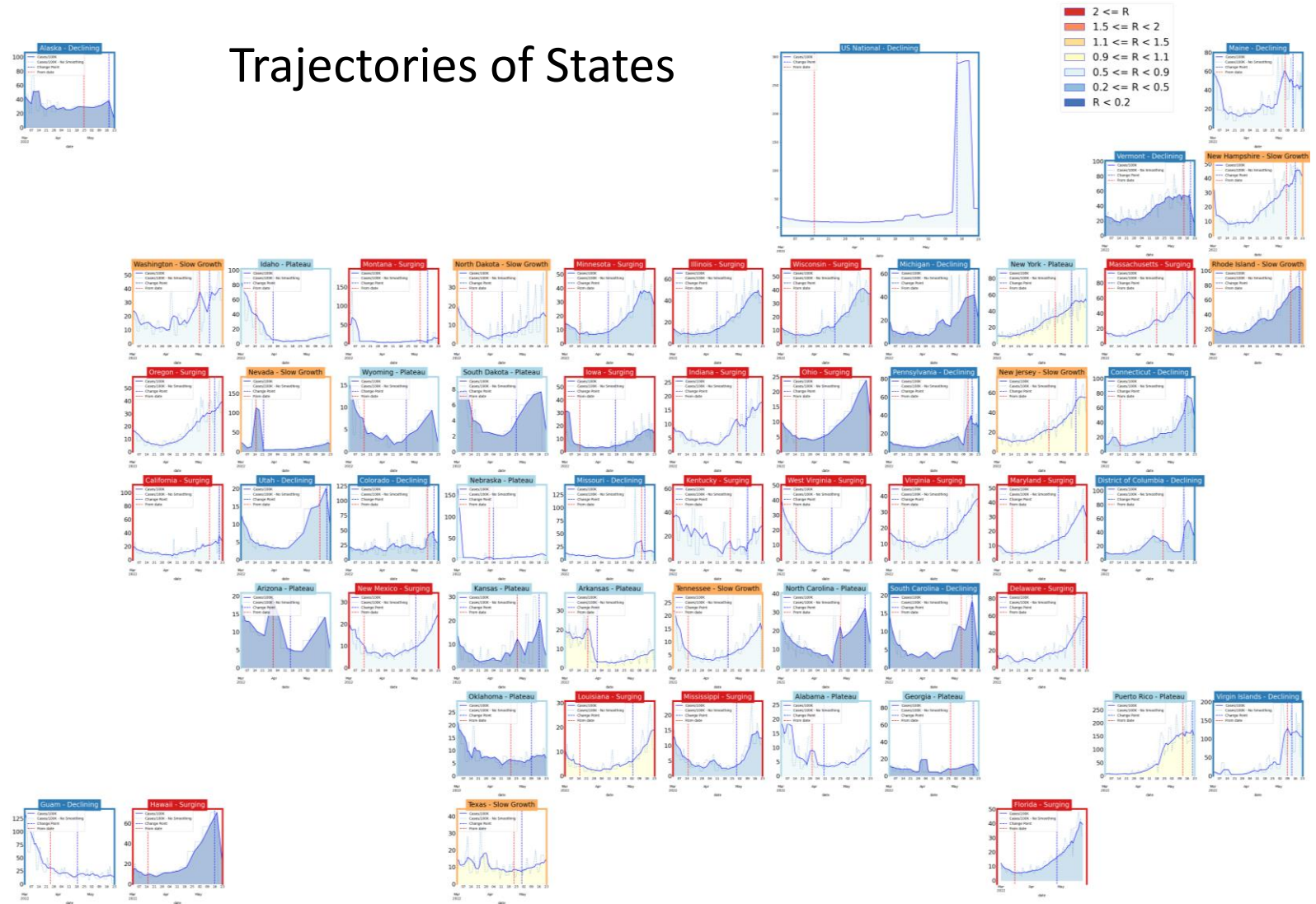
Epidemic and Variant Dynamics in South Africa



United States Case Rates

- Rebounding activity, mainly in the Northeast

Trajectories of States



Status # States

Declining 13 (7)

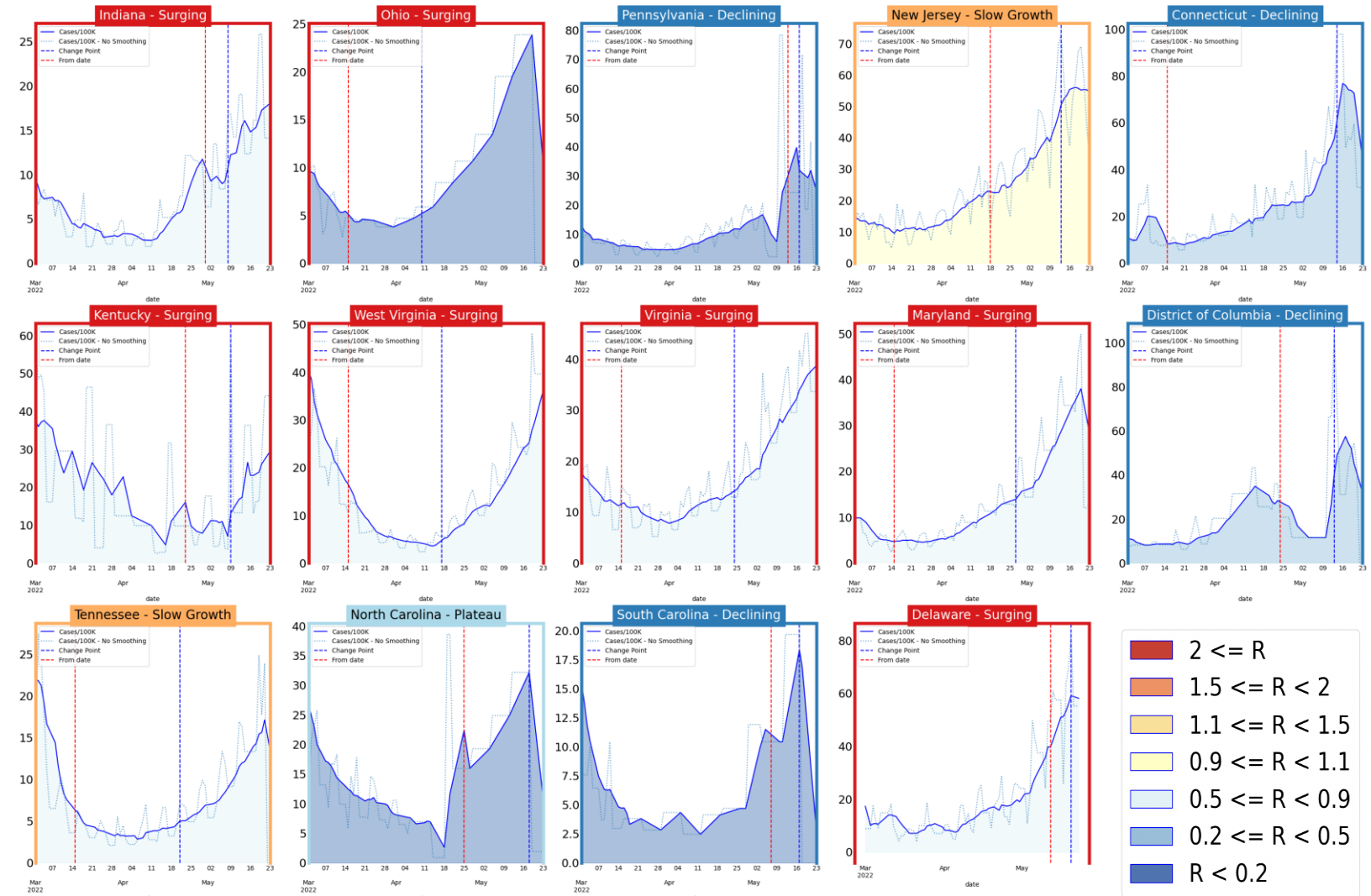
Plateau 13 (18)

Slow Growth 8 (7)

In Surge 20 (22)

Virginia and Her Neighbors

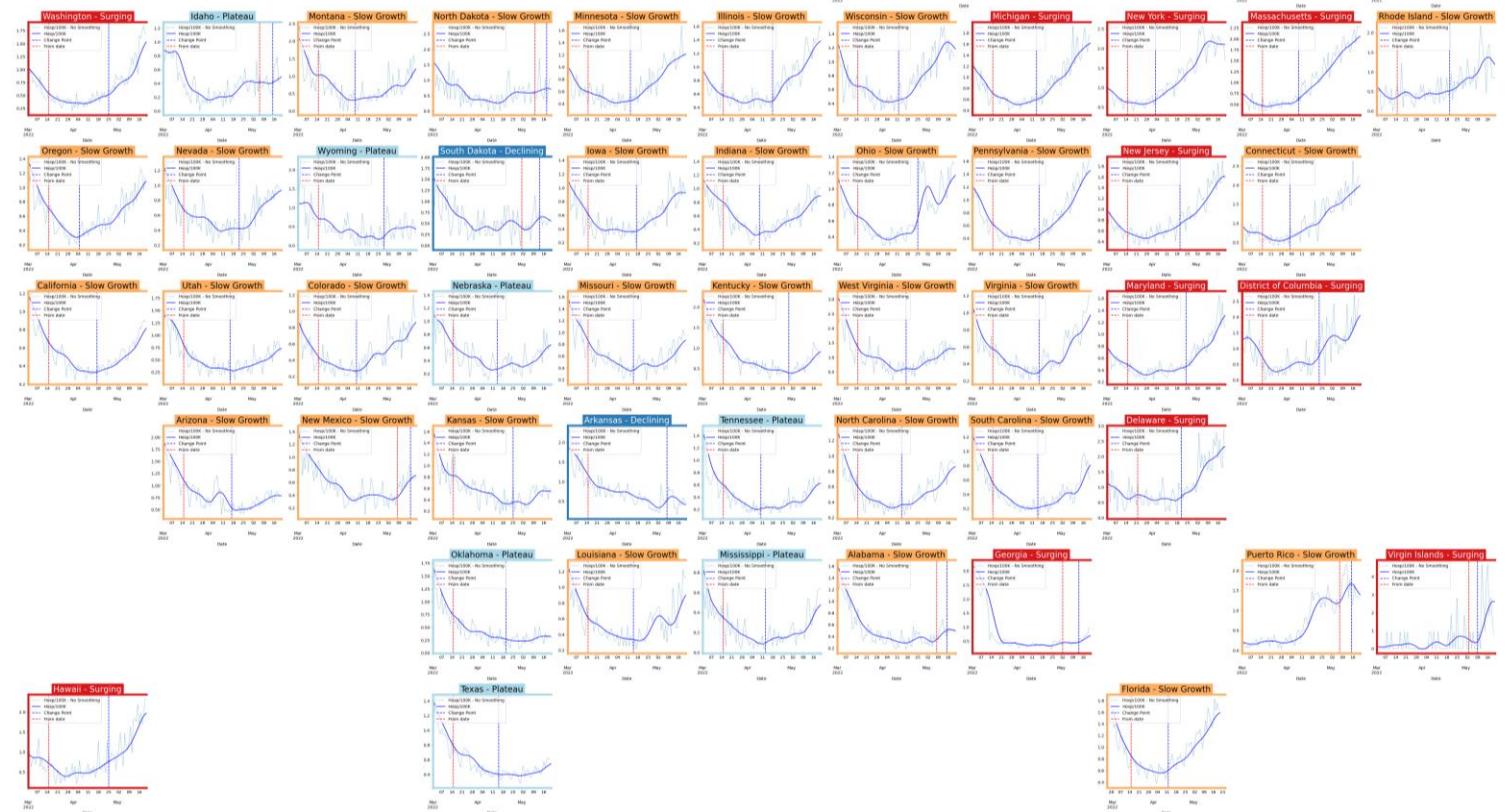
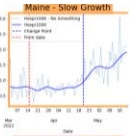
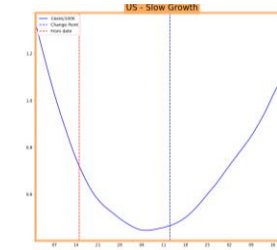
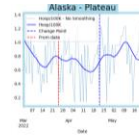
- Most states are in surge
- Some signs of slowing growth



United States Hospitalizations

- Hospital admissions are lagging case rates, and have mainly entered plateaus
- Rebounds in the Northeast seen with some rising hospitalization rates

Trajectories of States



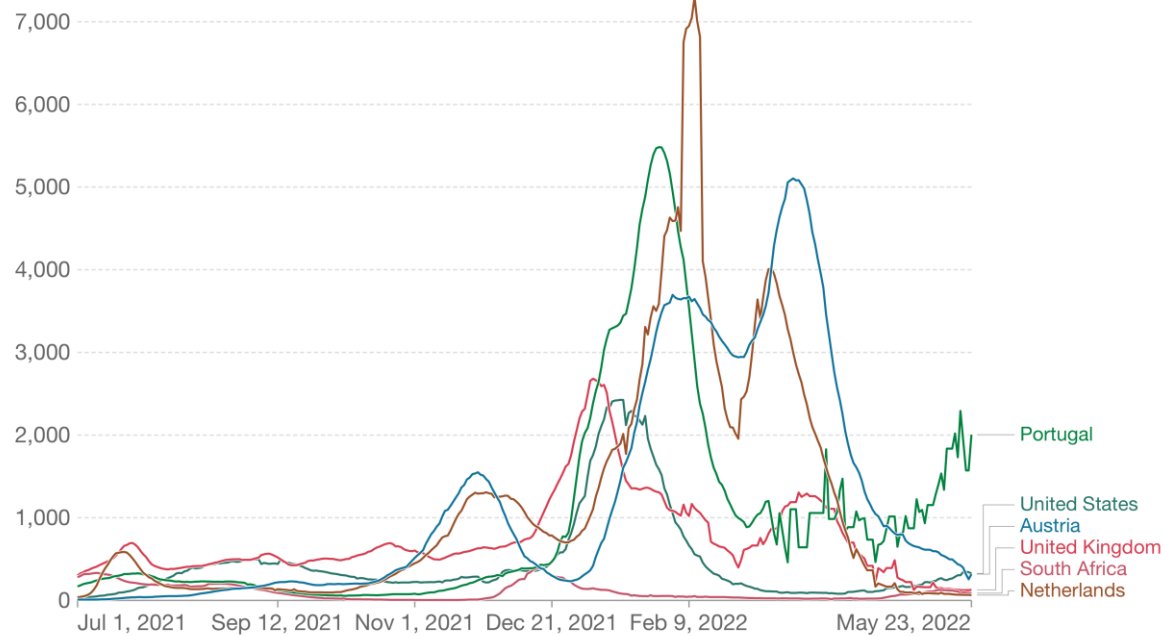
Status	# States
Declining	3 (1)
Plateau	8 (17)
Slow Growth	30 (28)
In Surge	12 (7)

Around the World – BA.4 and BA.5 impacted countries

Confirmed cases

Daily new confirmed COVID-19 cases per million people

7-day rolling average. Due to limited testing, the number of confirmed cases is lower than the true number of infections.



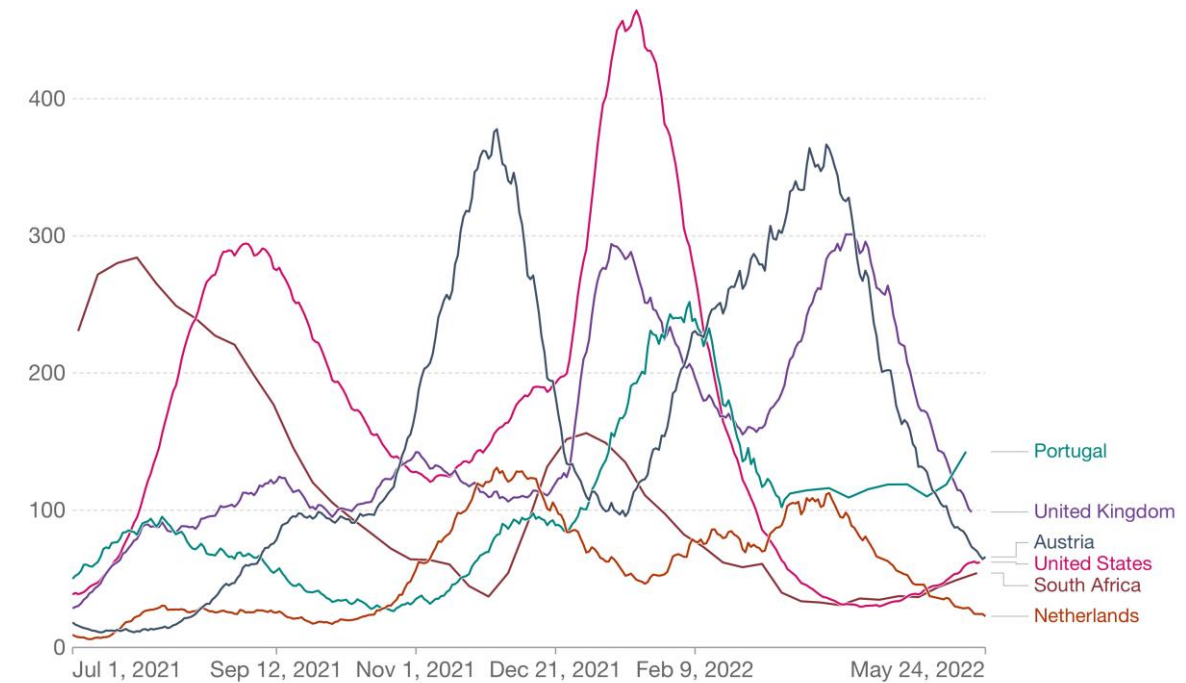
Source: Johns Hopkins University CSSE COVID-19 Data

Our World
in Data

CC BY

Hospitalizations

Number of COVID-19 patients in hospital per million people



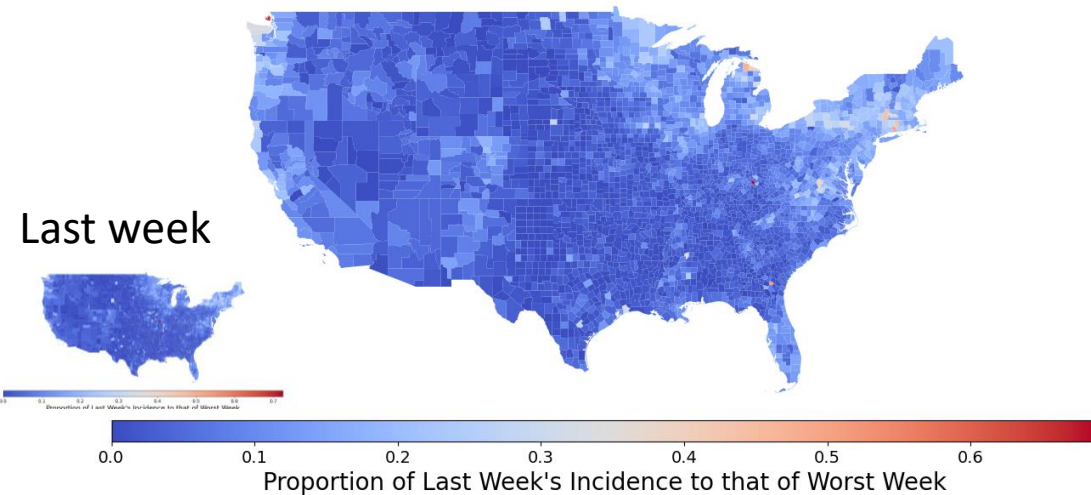
Source: Official data collated by Our World in Data

Our World
in Data

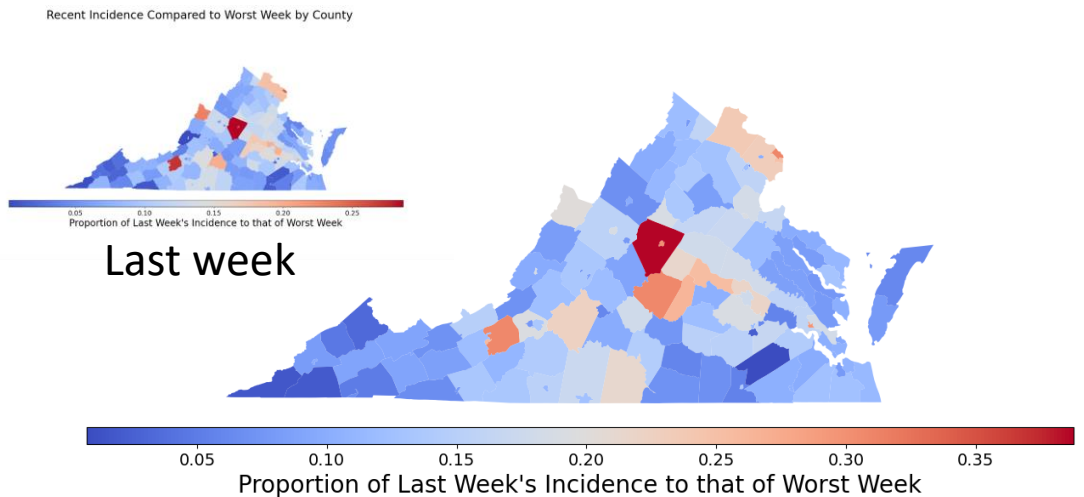
CC BY

County-level comparison to previous highest peak

Recent Incidence Compared to Worst Week by County



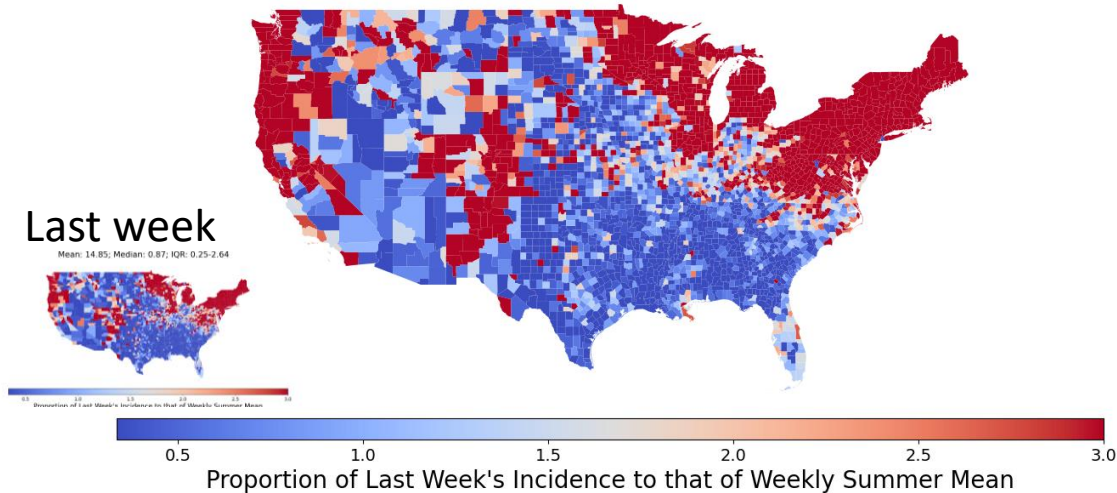
Recent Incidence Compared to Worst Week by County



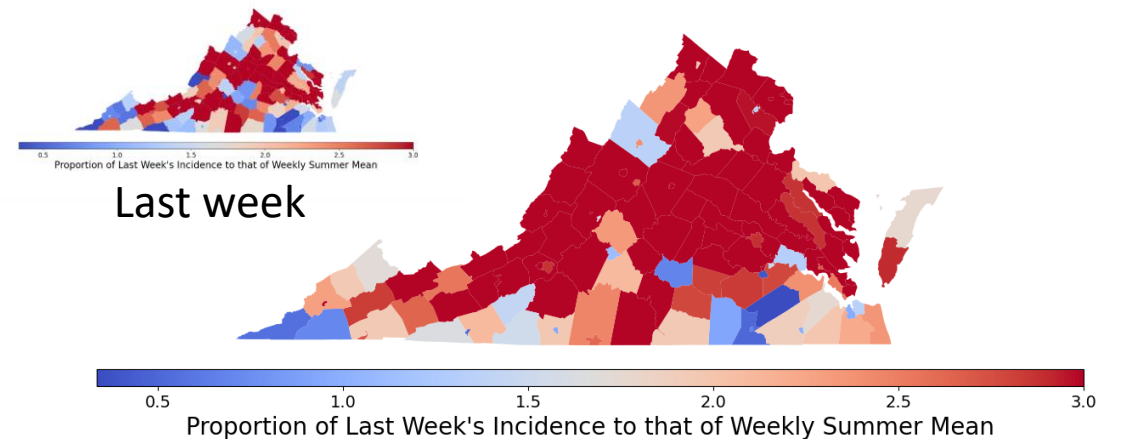
County-level comparison to last Summer

- Most counties in VA have had the highest case rate of the pandemic in the last week
- Nationally the number of counties at their highest rate has expanded considerably

Recent Incidence Compared to Weekly Summer Mean by County
Mean: 13.71; Median: 1.19; IQR: 0.4-3.74



Recent Incidence Compared to Weekly Summer Mean by County
Mean: 4.38; Median: 3.09; IQR: 1.99-5.37
Recent Incidence Compared to Weekly Summer Mean by County
Mean: 3.22; Median: 2.22; IQR: 1.34-4.04



Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

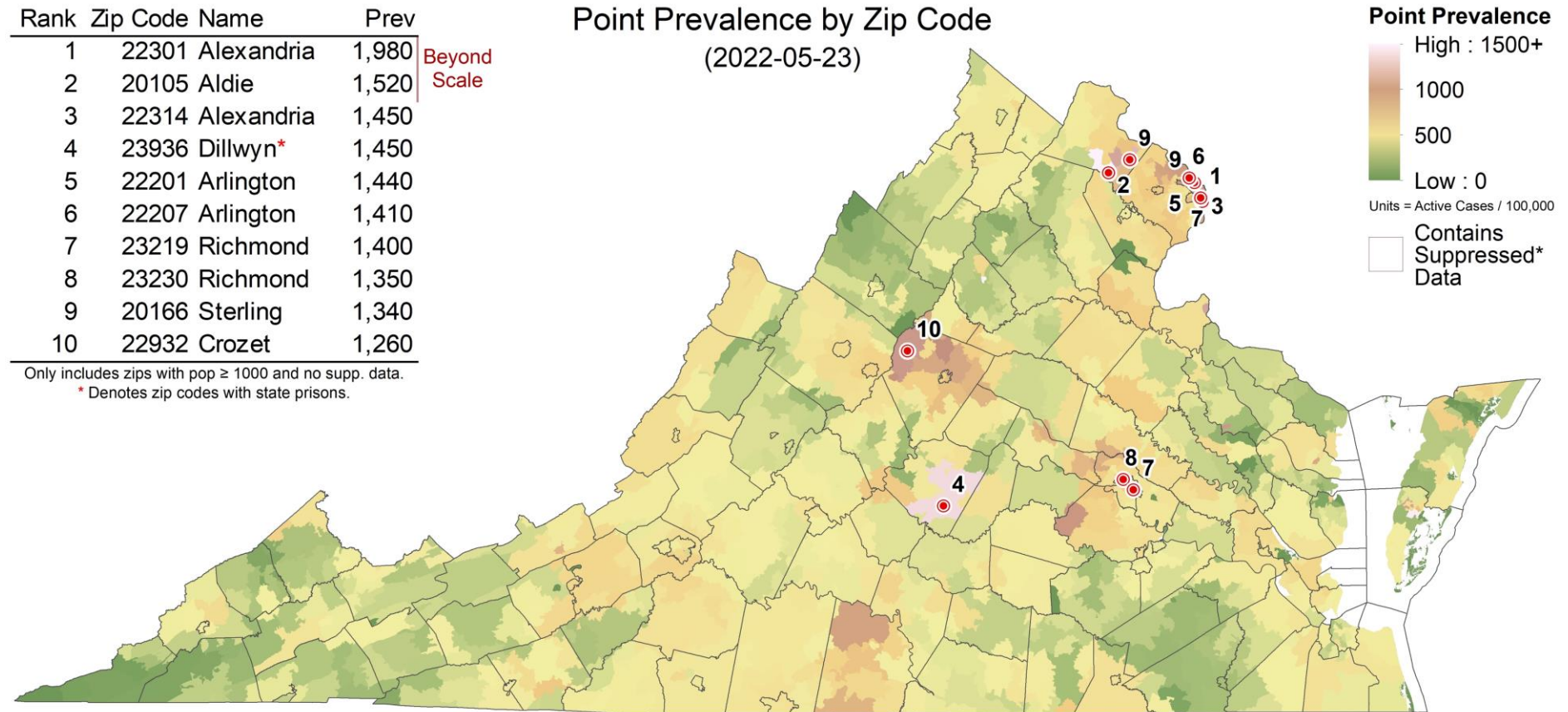
- Some counts are low and suppressed to protect anonymity, those are shown in white

Rank	Zip Code	Name	Prev
1	22301	Alexandria	1,980
2	20105	Aldie	1,520
3	22314	Alexandria	1,450
4	23936	Dillwyn*	1,450
5	22201	Arlington	1,440
6	22207	Arlington	1,410
7	23219	Richmond	1,400
8	23230	Richmond	1,350
9	20166	Sterling	1,340
10	22932	Crozet	1,260

Only includes zips with pop ≥ 1000 and no supp. data.

* Denotes zip codes with state prisons.

Point Prevalence by Zip Code
(2022-05-23)

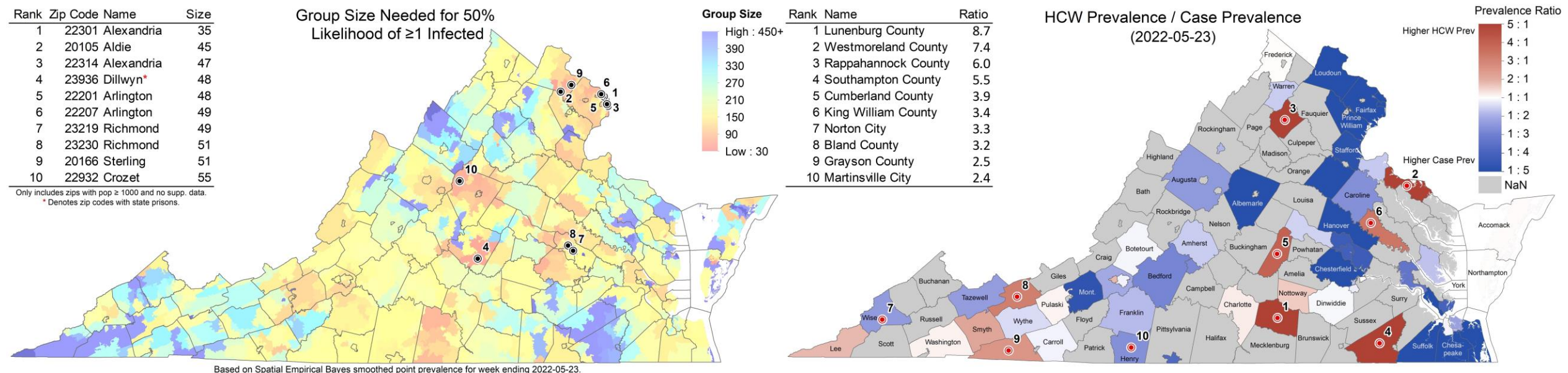


Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2022-05-23.

Risk of Exposure by Group Size and HCW prevalence

Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25)

- **Group Size:** Assumes 2 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey), and shows minimum size of a group with a 50% chance an individual is infected by zip code (eg in a group of 55 in Fort Eustis, there is a 50% chance someone will be infected)
- **HCW ratio:** Case rate among health care workers (HCW) in the last week using patient facing health care workers as the denominator / general population's case prevalence

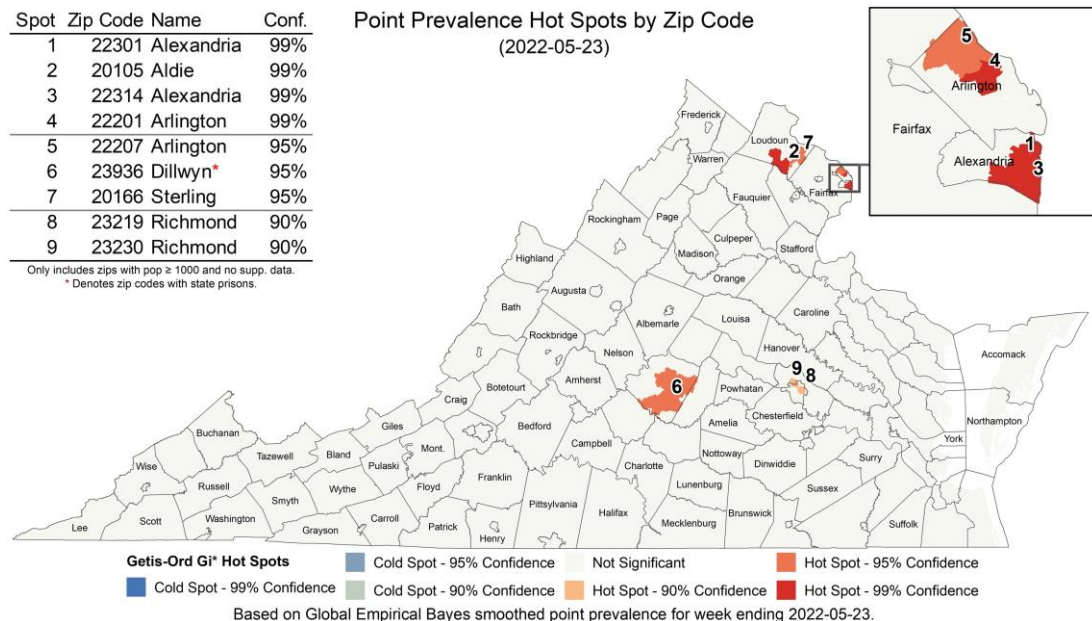


Current Hot-Spots

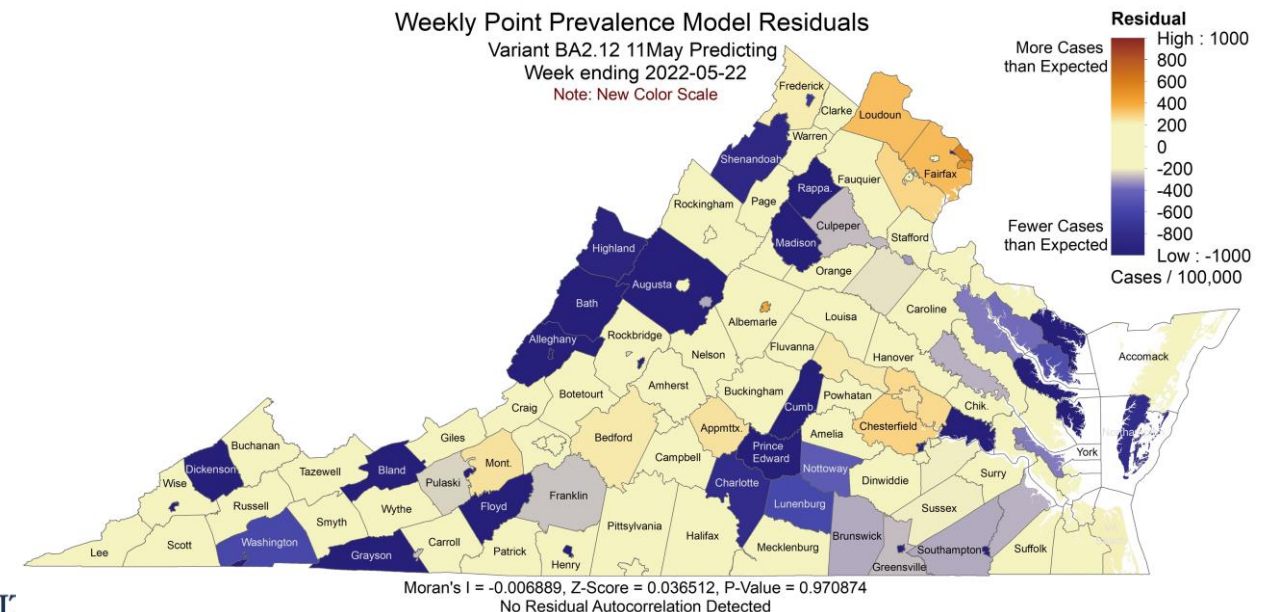
Case rates that are significantly different from neighboring areas or model projections

- **Spatial:** Getis-Ord Gi* based hot spots compare clusters of zip codes with weekly case prevalence higher than nearby zip codes to identify larger areas with statistically significant deviations
- **Temporal:** The weekly case rate (per 100K) projected last week compared to observed by county, which highlights temporal fluctuations that differ from the model's projections

Spatial Hotspots



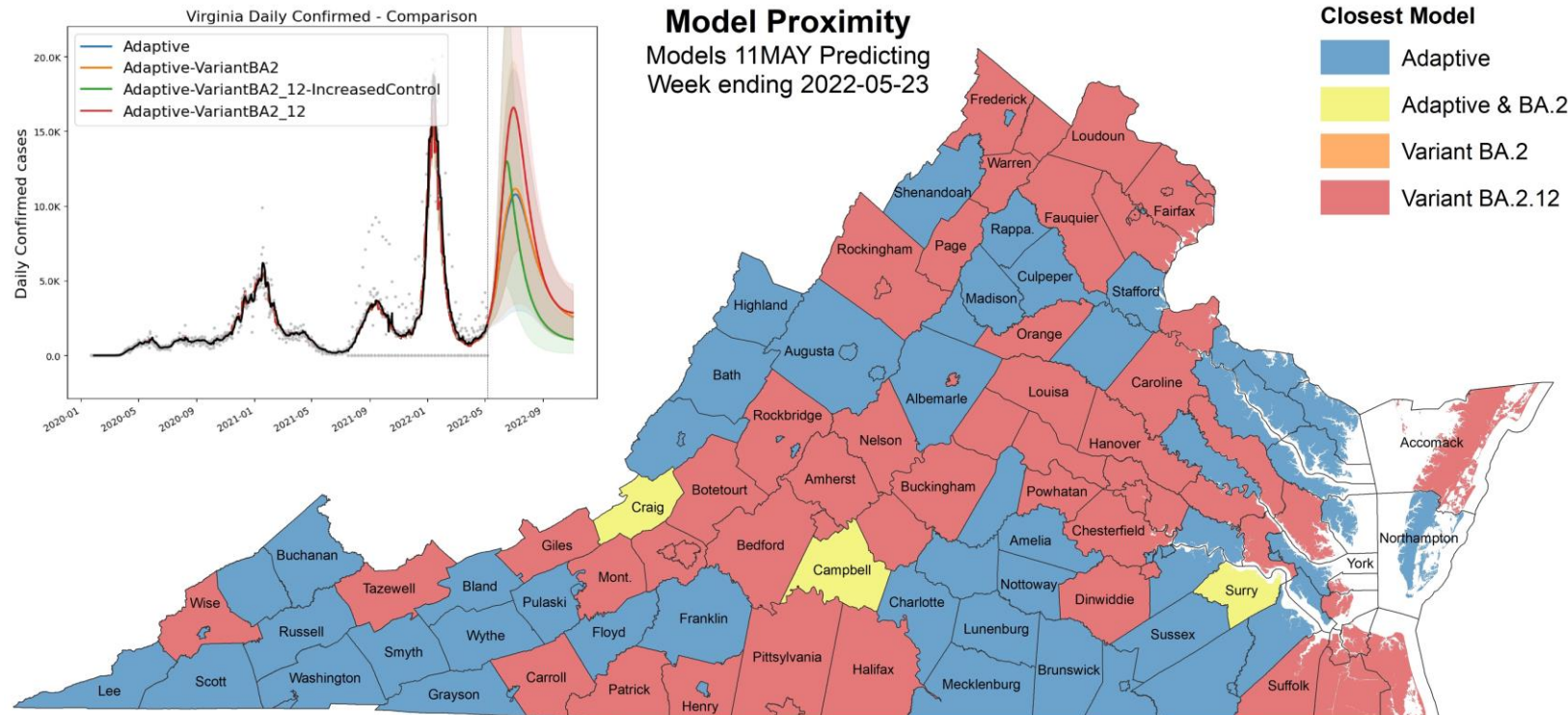
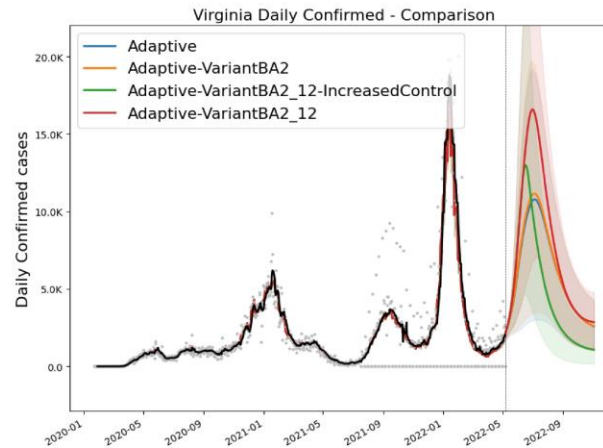
Clustered Temporal Hotspots (from BA.2.12.1)



Scenario Trajectory Tracking

Which scenario from last projection did each county track closest?

- Minimal difference between projections overall
- State level trend tracking BA.2.12.1 scenarios (red and green), but not all, likely due to variation in prevalence across the state

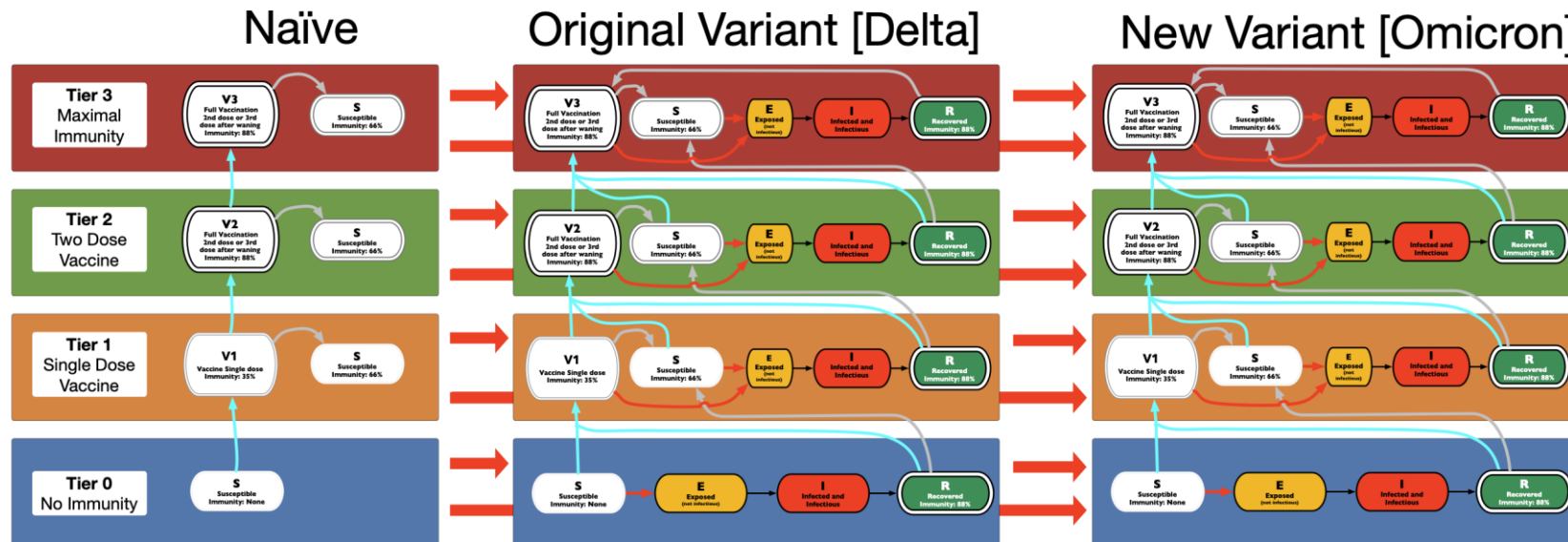


Model Update – Adaptive Fitting

Model Structure Extended for Multiple Strains

Omicron escapes immunity from vaccinated and those infected with Delta

- Multiple strain support allows representation of differential protection based on immunological history
- Severity of outcomes varies by strain and level of immunity, thus allowing model to better capture hospitalizations and deaths from Omicron
- Adaptive fitting approach continues to use simulation to generate the full distribution of immune states across the population



Adaptive Fitting Approach

Each county fit precisely, with recent trends used for future projection

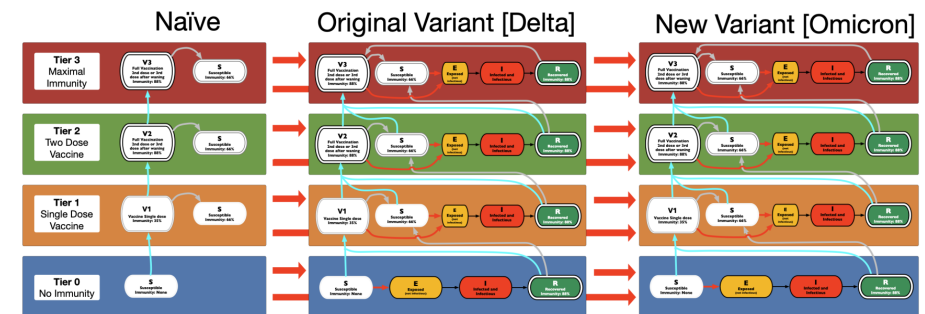
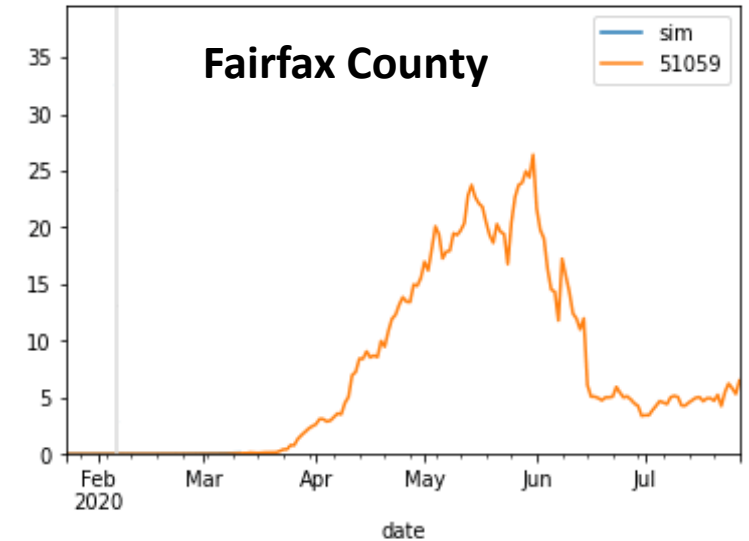
- Allows history to be precisely captured, and used to guide bounds on projections

Model: An alternative use of the same meta-population model, PatchSim with multiple tiers of immunity

- Allows for future “what-if” Scenarios to be layered on top of calibrated model
- Allows for waning of immunity and for partial immunity against different outcomes (eg lower protection for infection than death)

External Seeding: Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions, we use steady 1 case per 10M population per day external seeding



Using Ensemble Model to Guide Projections

Ensemble methodology that combines the Adaptive with machine learning and statistical models such as:

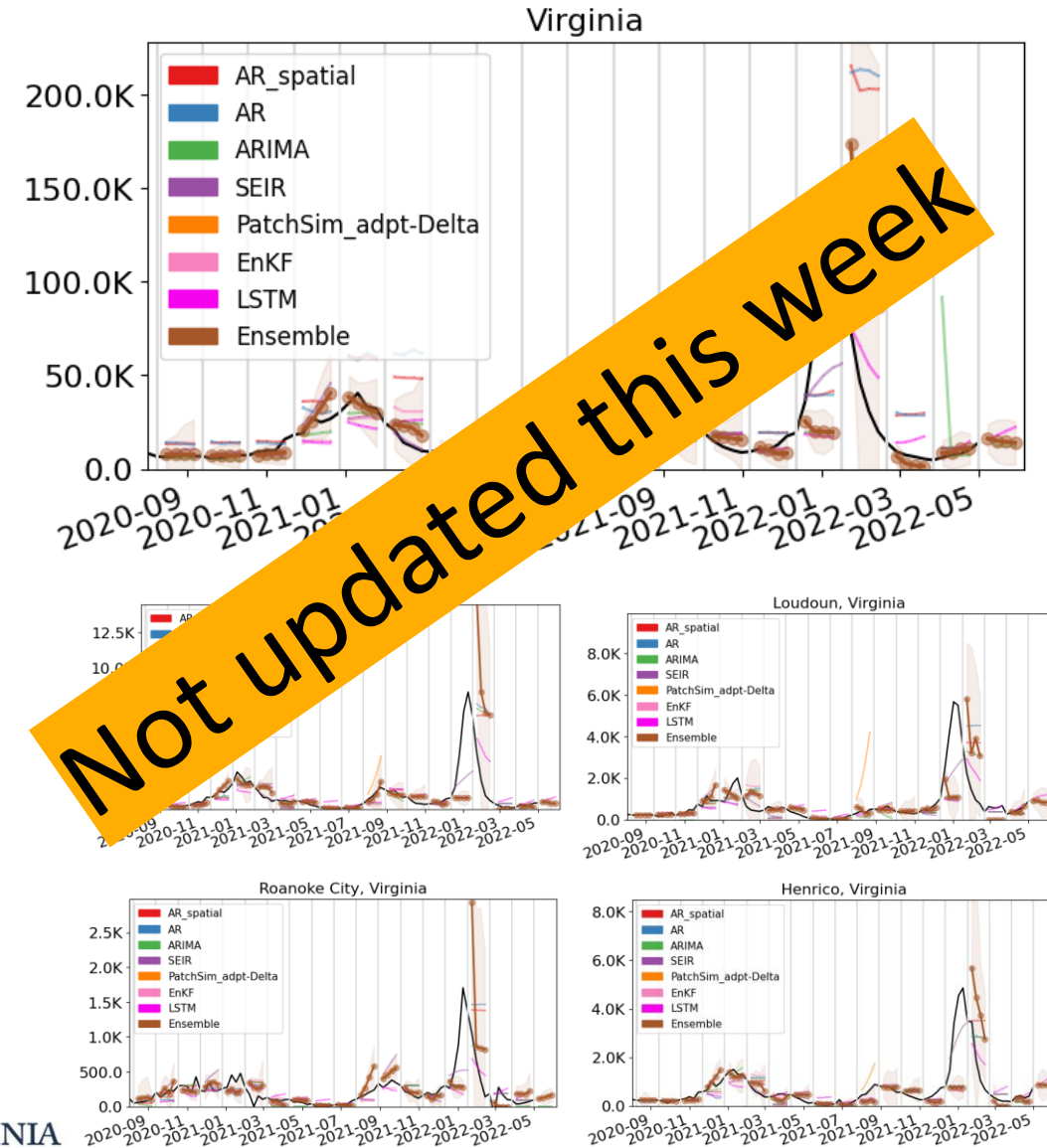
- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

Weekly forecasts done at county level.

Models chosen because of their track record in disease forecasting and to increase diversity and robustness.

Ensemble forecast provides additional 'surveillance' for making scenario-based projections.

Also submitted to CDC Forecast Hub.



Seroprevalence updates to model design

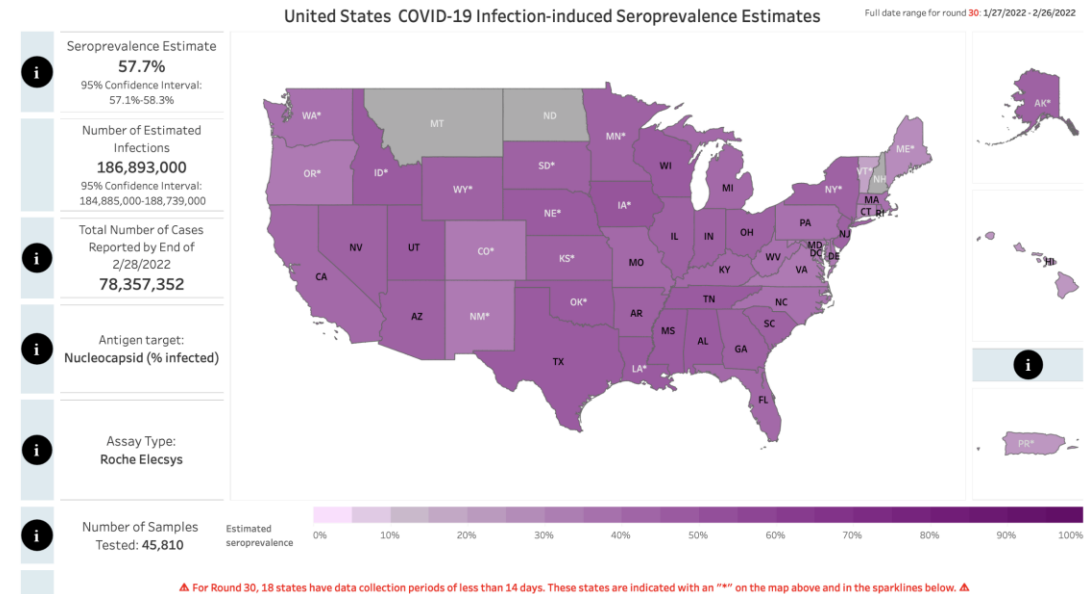
Several seroprevalence studies provide better picture of how many actual infections have occurred

- CDC Nationwide Commercial Laboratory Seroprevalence Survey

Pre-Omicron these findings were consistent with an ascertainment ratio of ~2-3x

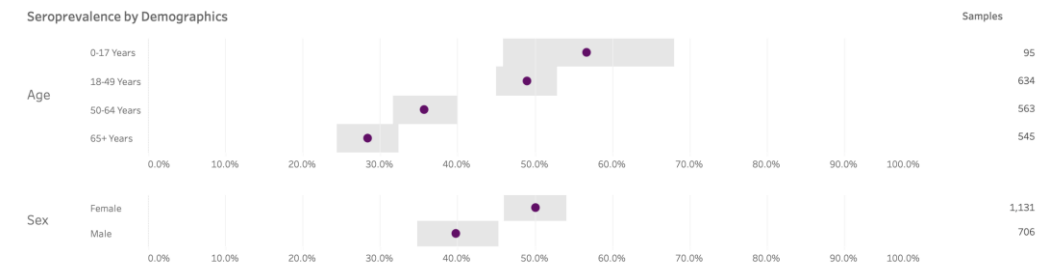
- Thus there were 2.5 total infections in the population for every confirmed case recently
- **Case ascertainment for Omicron infections are half of that for pre-Omicron, thus for every case there are ~5 total infections**
- During the peak of Omicron, the degradation of test seeking and capacity were modeled to have fallen by 3x with a rebound to pre-Omicron levels by mid-Feb

New Data released late on April 26th not yet incorporated in model



Virginia

Feb 22nd: 45% [42% - 48%]; Jan 22nd: 34% [31%-39%]



Calibration Approach

- **Data:**
 - County level case counts by date of onset (from VDH)
 - Confirmed cases for model fitting
- **Calibration:** fit model to observed data and ensemble's forecast
 - Tune transmissibility across ranges of:
 - Duration of incubation (5-9 days), infectiousness (3-7 days)
 - Undocumented case rate (1x to 7x) guided by seroprevalence studies
 - Detection delay: exposure to confirmation (4-12 days)
 - Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak
- **Project:** future cases and outcomes generated using the collection of fit models run into the future
 - **Mean trend from last 7 days of observed cases and first week of ensemble's forecast used**
 - Outliers removed based on variances in the previous 3 weeks
 - 2 week interpolation to smooth transitions in rapidly changing trajectories
- **Outcomes:** Data driven by shift and ratio that has least error in last month of observations
 - Hospitalizations: 3 days from confirmation, 6.8% of cases hospitalized
 - Deaths: 11 days from confirmation, 1.45% of cases die



COVID-19 in Virginia: Summary

Dashboard Updated: 5/25/2022
Data entered by 5:00 PM the prior day.



Cases, Hospitalizations and Deaths					
Total Cases*		Total Hospital Admissions**		Total Deaths	
1,770,620		51,415		20,358	
(New Cases: 3,488)^					
Confirmed†	Probable†	Confirmed†	Probable†	Confirmed†	Probable†
1,267,904	502,716	48,307	3,108	16,992	3,366

* Includes both people with a positive test (Confirmed), and symptomatic with a known exposure to COVID-19 (Probable).

** Hospitalization of a case is captured at the time VDH performs case investigation. This underrepresents the total number of hospitalizations in Virginia.

^New cases represent the number of confirmed and probable cases reported to VDH in the past 24 hours.

† VDH adopted the updated CDC COVID-19 confirmed and probable surveillance case definitions on August 27, 2020. Found here: <https://www.cdc.gov/nndss/conditions/coronavirus-disease-2019-covid-19/case-definition/2020/08/05/>

Source: Cases - Virginia Electronic Disease Surveillance System (VEDSS), data entered by 5:00 PM the prior day.

Outbreaks	
Total Outbreaks*	Outbreak Associated Cases
8,403	137,498

* At least two (2) lab confirmed cases are required to classify an outbreak.

Testing (PCR Only)	
Testing Encounters PCR Only*	Current 7-Day Positivity Rate PCR Only**
13,785,942	17.2%

* PCR refers to "Reverse transcriptase polymerase chain reaction laboratory testing."

** Lab reports may not have been received yet. Percent positivity is not calculated for days with incomplete data.

Multisystem Inflammatory Syndrome in Children	
Total Cases*	Total Deaths
175	1

*Cases defined by CDC HAN case definition: <https://emergency.cdc.gov/han/2020/han00437.asp>

Accessed 8:45am May 25, 2022

<https://www.vdh.virginia.gov/coronavirus/>



Scenarios – Transmission Conditions

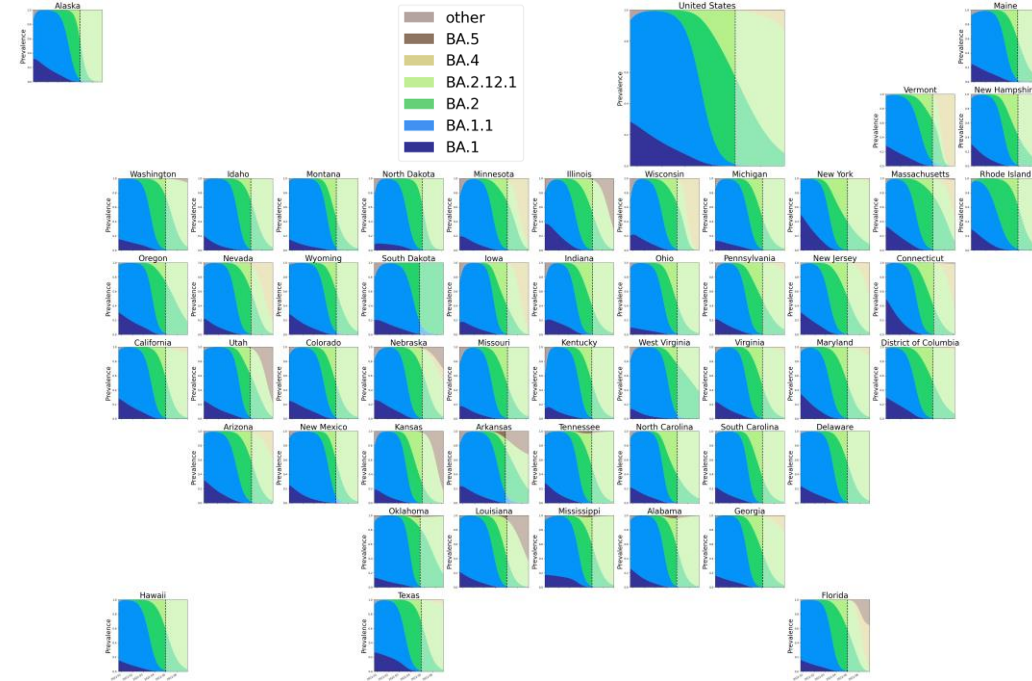
- Variety of factors continue to drive transmission rates
 - Seasonal impact of weather patterns, travel and gatherings, fatigue and premature relaxation of infection control practices
- **Waning Immunity:** Mean of 6 months to a year protection (rate of 0.0027) similar to [Pfizer study](#), Omicron waning with a mean of 4 months
- **Projection Scenarios:**
 - **Adaptive:** Control remains as is currently experienced into the future with assumption that Omicron remains as the majority strain, and that infection with Omicron provides protection against Omicron infection in the future
 - **Adaptive-VariantBA2_12:** Same as Adaptive, but with BA.2.12.1 subvariant continuing predominance and having a 30% transmission advantage over existing Omicron (mainly the overall BA.2 subvariant)
 - **Adaptive-VariantBA2_12-IncreasedControl:** Same as Adaptive-VariantBA2_12, but with a 25% reduction in transmission to increased mitigations starting in 30 days and phasing into full effect over 2 weeks
 - **Adaptive-VariantBA4:** Same as Adaptive, but with BA.4 / BA.5 subvariant in the future that has further immune escape (30%) from the existing Omicron subvariants

Scenarios – Omicron BA.2.12 Description

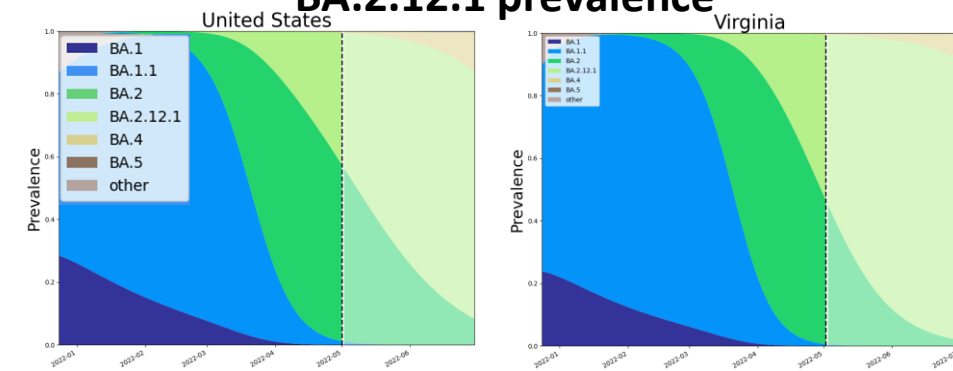
BA.2.12.1 shows signs of increased transmissibility via increasing prevalence in the US,

- **Transmissibility:** Not as well observed as previous VoCs as mainly in US and worldwide genotyping efforts have slowed
- **Using a 30% boost to transmissibility**
- **Prevalence:** Growth rate compared to BA.2 seems to be similar as to BA.2's vs. BA.1 (and BA.1.1), thus assuming similar prevalence curve (30% growth advantage, doubling ~every 8 days)
- **Prevalence estimated to have hit 50% on May 17th with ~95% 4 weeks later**
- **Severity:** Assumed to be same as for other Omicron subvariants

Observed BA.2.12.1 prevalence



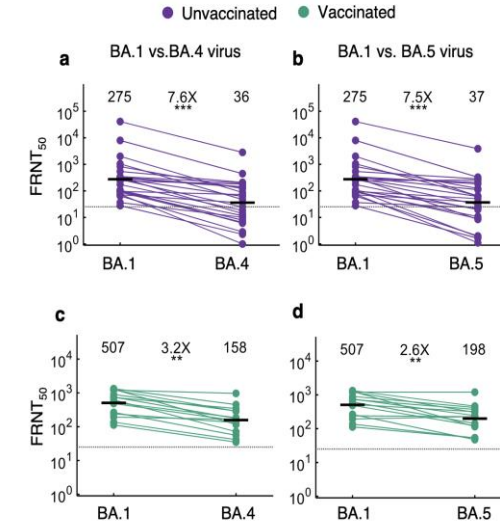
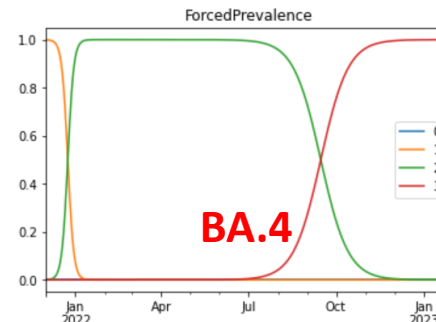
Coarse Polynomial fitted estimates of BA.2.12.1 prevalence



Scenarios – Omicron BA.4 Description

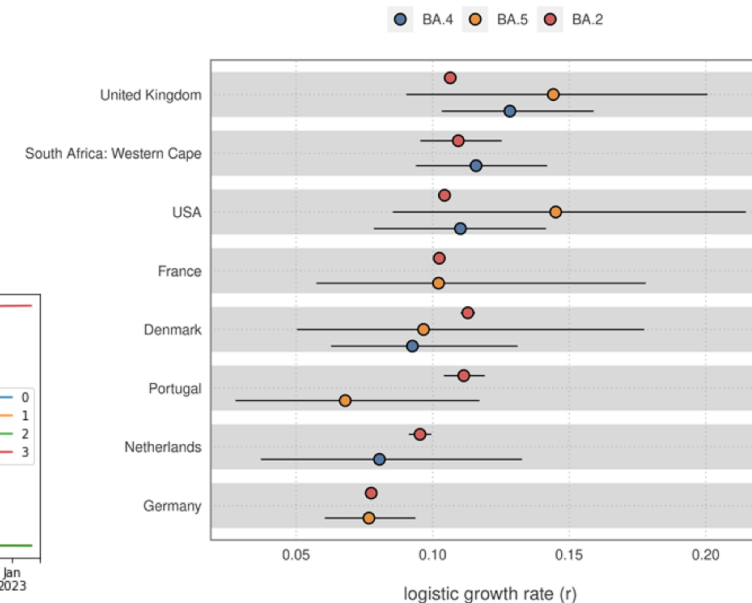
BA.4 and BA.5 subvariants are showing significant growth in some countries

- **Immune Escape:** Lab studies demonstrate that BA.4 and BA.5 demonstrate immune escape for both vaccinated and vaccinated people who have been previously infected with BA.1 subvariants
- **Using a 30% reduction in immunity for those previously infected with Omicron (BA.1 and BA.2)**
- **Transmissibility:** Lab studies suggest may actually be less transmissible. Assume equal to BA.2.12.1
- **Prevalence:** Growth rate is challenging to estimate, speculative future prevalence scenario used.
 - **Conservatively estimating initial pick up in June, with 50% on Oct 1st**
- **Severity:** Assumed to be same as for other Omicron subvariants



Researchers in SA isolated live BA.4 and BA.5 viruses and tested them against neutralizing immunity elicited to BA.1 infection in participants who were Omicron/BA.1 infected but unvaccinated (n=24) and participants vaccinated with Pfizer BNT162b2 or Johnson and Johnson Ad26.CoV.2S with breakthrough Omicron/BA.1 infection (n=15)

<https://www.medrxiv.org/content/10.1101/2022.04.29.22274477v1>



The estimated growth rate for BA.4 and BA.5 replacing BA.2 is compared with the rate at which BA.2 replaced BA.1. The analysis is unable to entirely statistically differentiate the rates for the ongoing replacement of BA.2 by BA.4 and BA.5 as being faster or slower than the replacement of BA.1 by BA.2. In all countries, the credible intervals for the rate being faster / slower cross one (equivalence).

[UK HSA report](#)

Projection Scenarios – Combined Conditions

Name	Txm Controls	Vax	Description
Adaptive	C	SQ	Likely trajectory based on conditions remaining similar to the current experience, includes immune escape due to Omicron
Adaptive-VariantBA2_12	C	SQ	Transmission rates for BA.2.12.1 infections are and additional 30% higher, with BA.2.12.1 prevalence reaching 50% on June 1 st and rising to ~95% 4 weeks after
Adaptive-VariantBA2_12-IncreasedControl	Increased	SQ	Same as Adaptive-VariantBA2_12 with increased mitigations reducing transmission by 25% starting in 30 days
Adaptive-VariantBA4	C	SQ	Transmission rates for BA.4 infections are 30% immune escaping from previous infections of Omicraon (BA.1 and BA.2) using a speculative future prevalence reaching 50% on October 1 st

Transmission Controls:

C = Current levels persist into the future

Increased = Transmission rates are reduced by 25% over 2 weeks starting May 1st

Spring = Transmission rates from mid-Jan 2021 through mid-March 2021 are coarsely replayed, representing a 60% reduction in transmission rate drivers, with Omicron remaining dominant

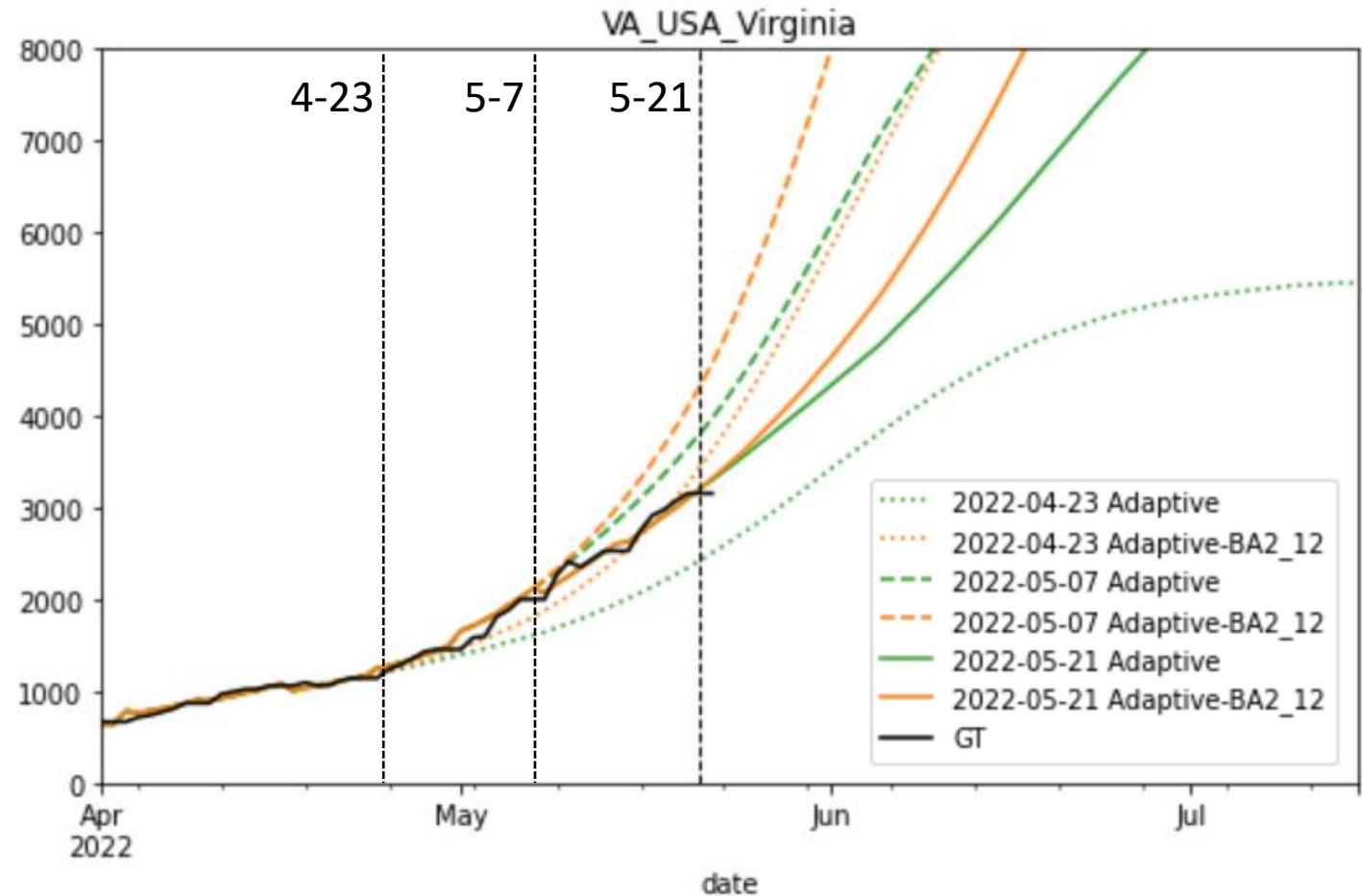
Vaccinations:

SQ = Status quo acceptance leads to low rates of vaccination through the summer

VO = Vaccination acceptance optimistically expands with increased rates through the summer

Last projection comparison – 2 and 4 weeks ago

- Growth to present still tracking April 23rd BA.2.12.1 scenario (orange dotted)
- Solid lines are current projections, dashed lines are from 2 weeks ago, slight uptick led to over estimation
- Current projections slightly lower than 4-23

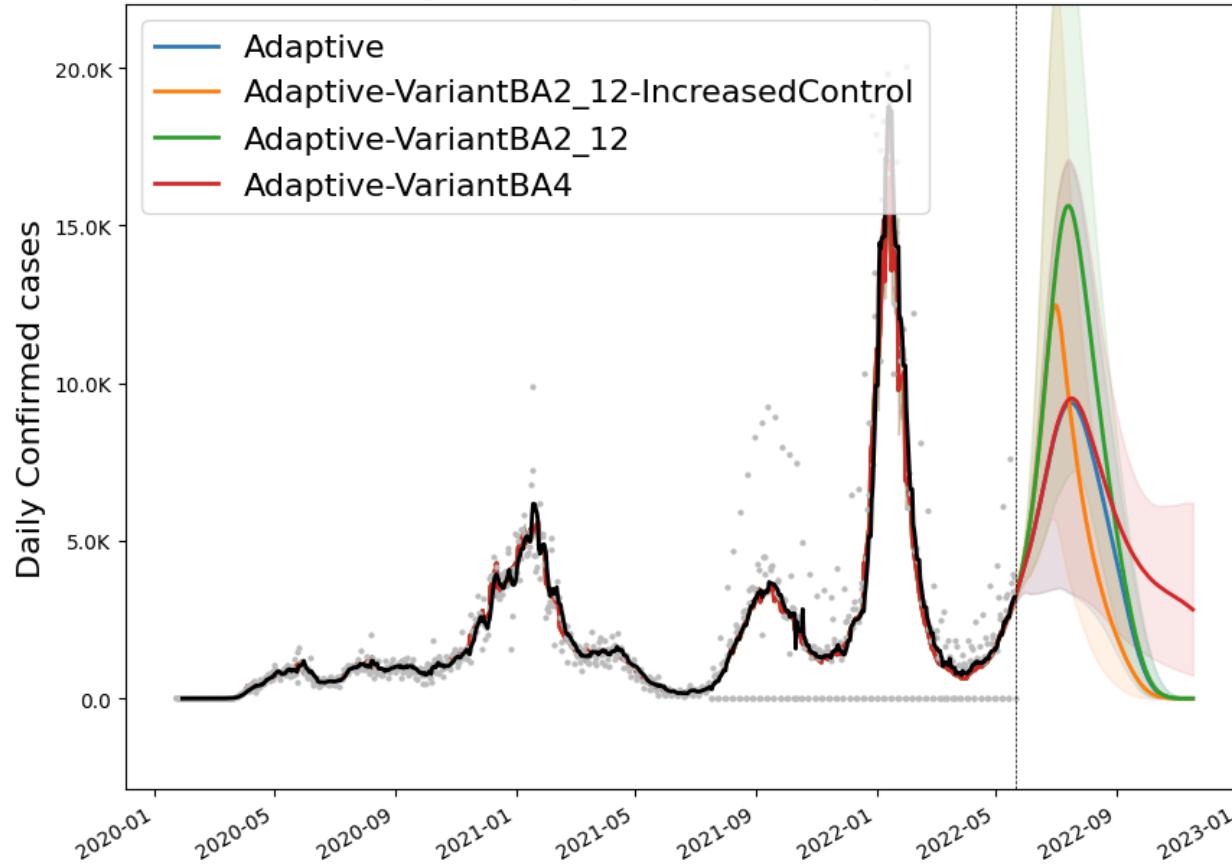


Model Results

Outcome Projections

Confirmed cases

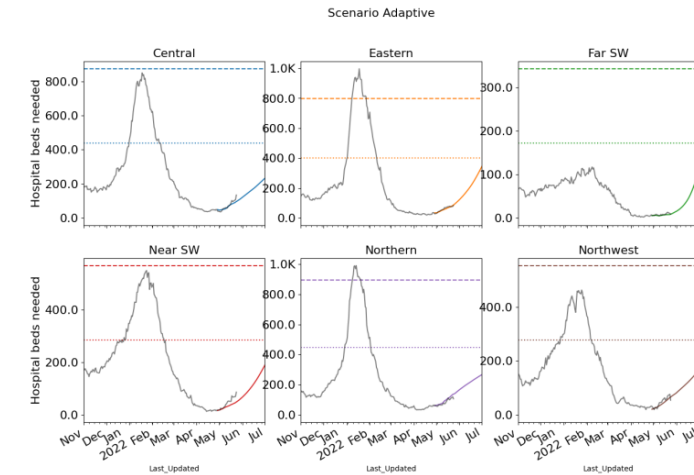
Virginia Daily Confirmed - Comparison



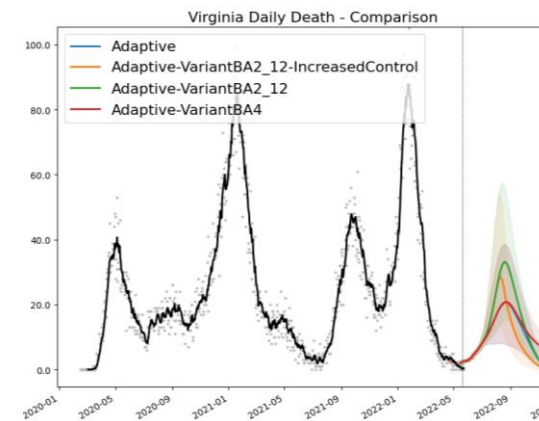
* without surveillance correction VariantBA2 peaked over 10K in July



Estimated Hospital Occupancy

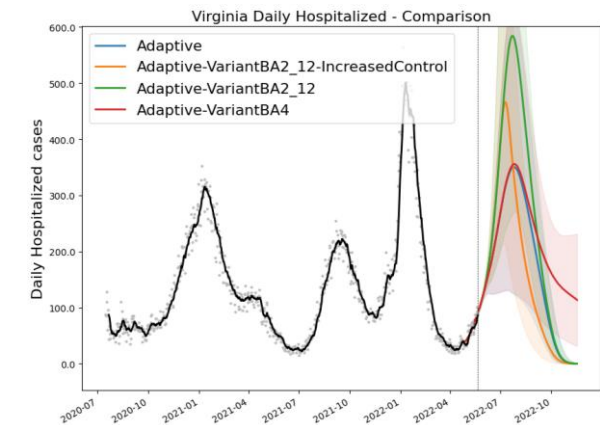


Daily Deaths



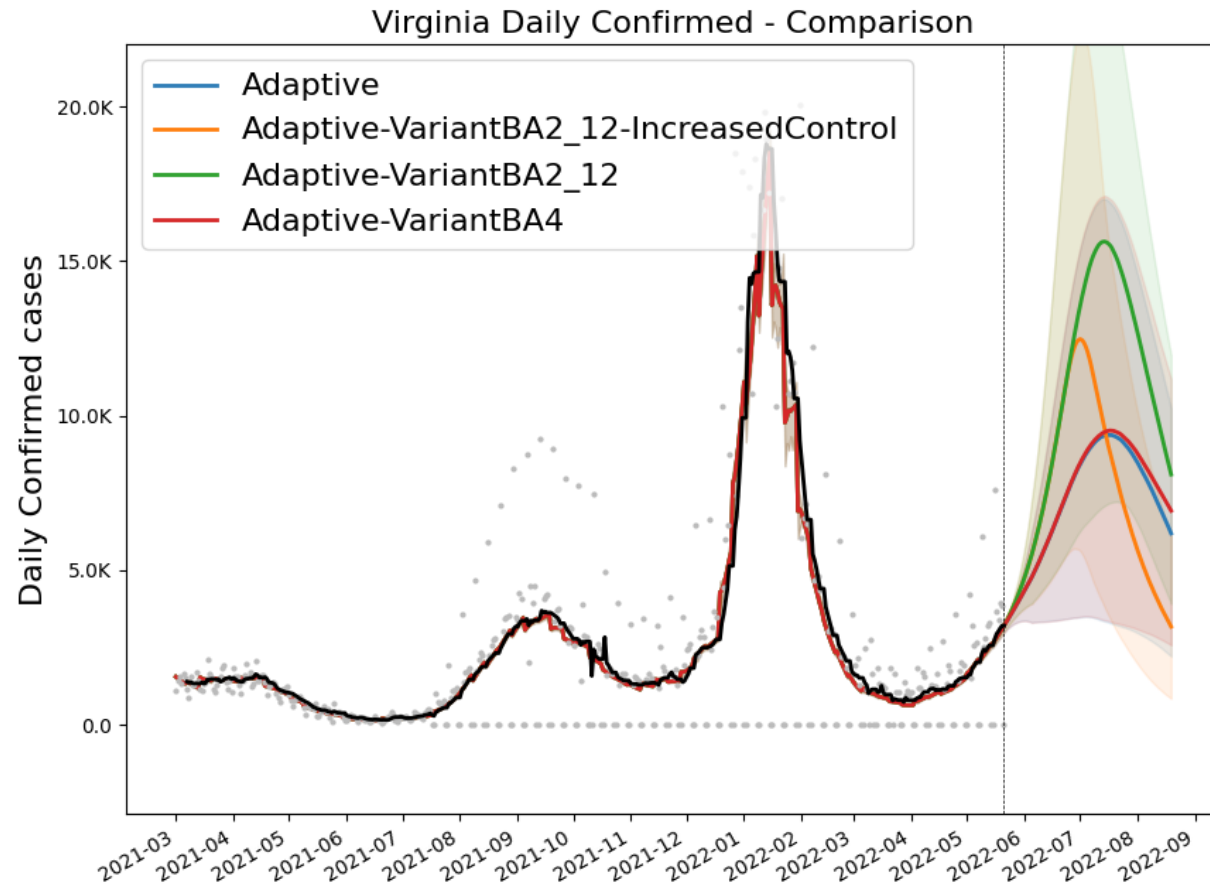
Death ground truth from VDH "Event Date" data, most recent dates are not complete

Daily Hospitalized



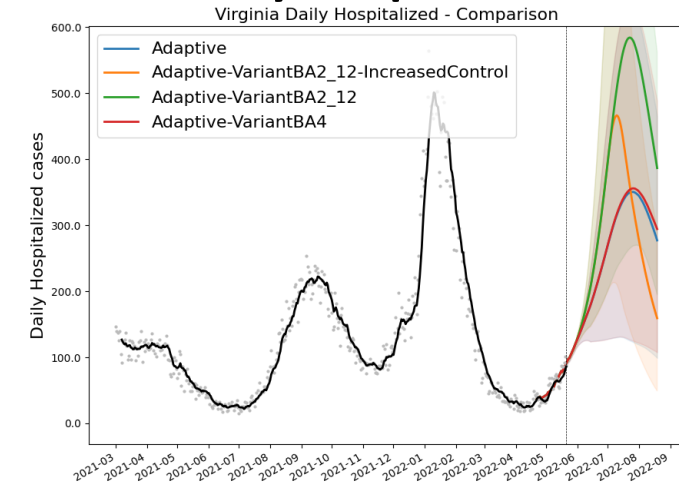
Outcome Projections – Closer Look

Confirmed cases

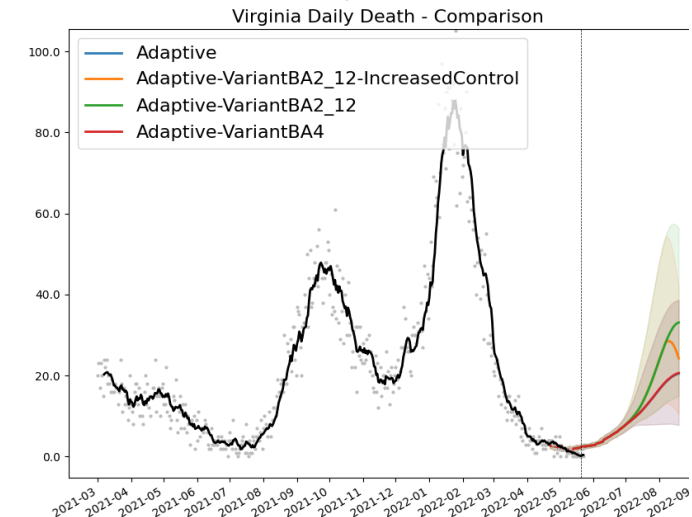


* without surveillance correction VariantBA2 peaked over 10K in July

Daily Hospitalized



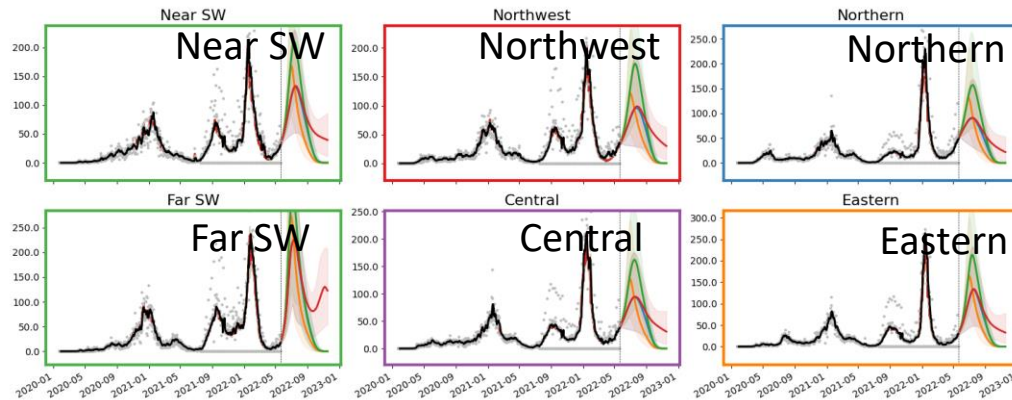
Daily Deaths



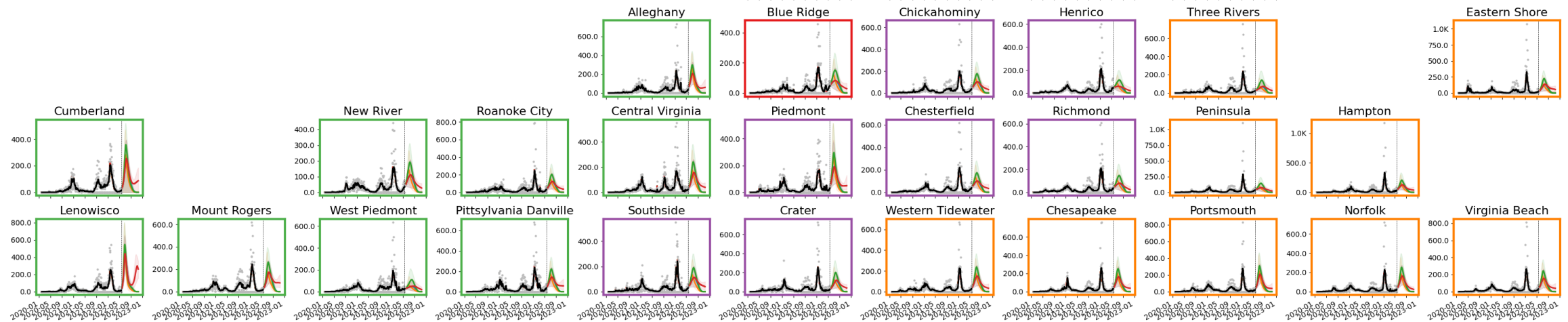
Death ground truth from VDH "Event Date" data, most recent dates are not complete

Detailed Projections: All Scenarios

Projections by Region



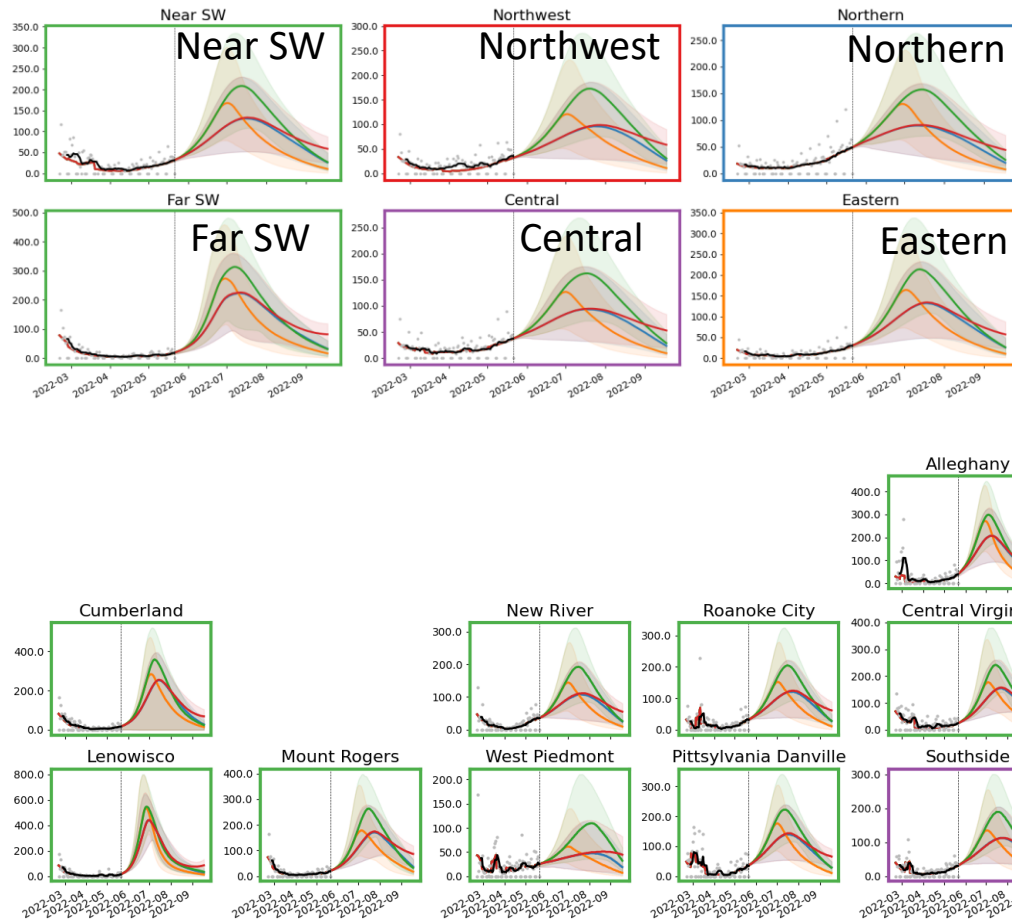
Projections by District



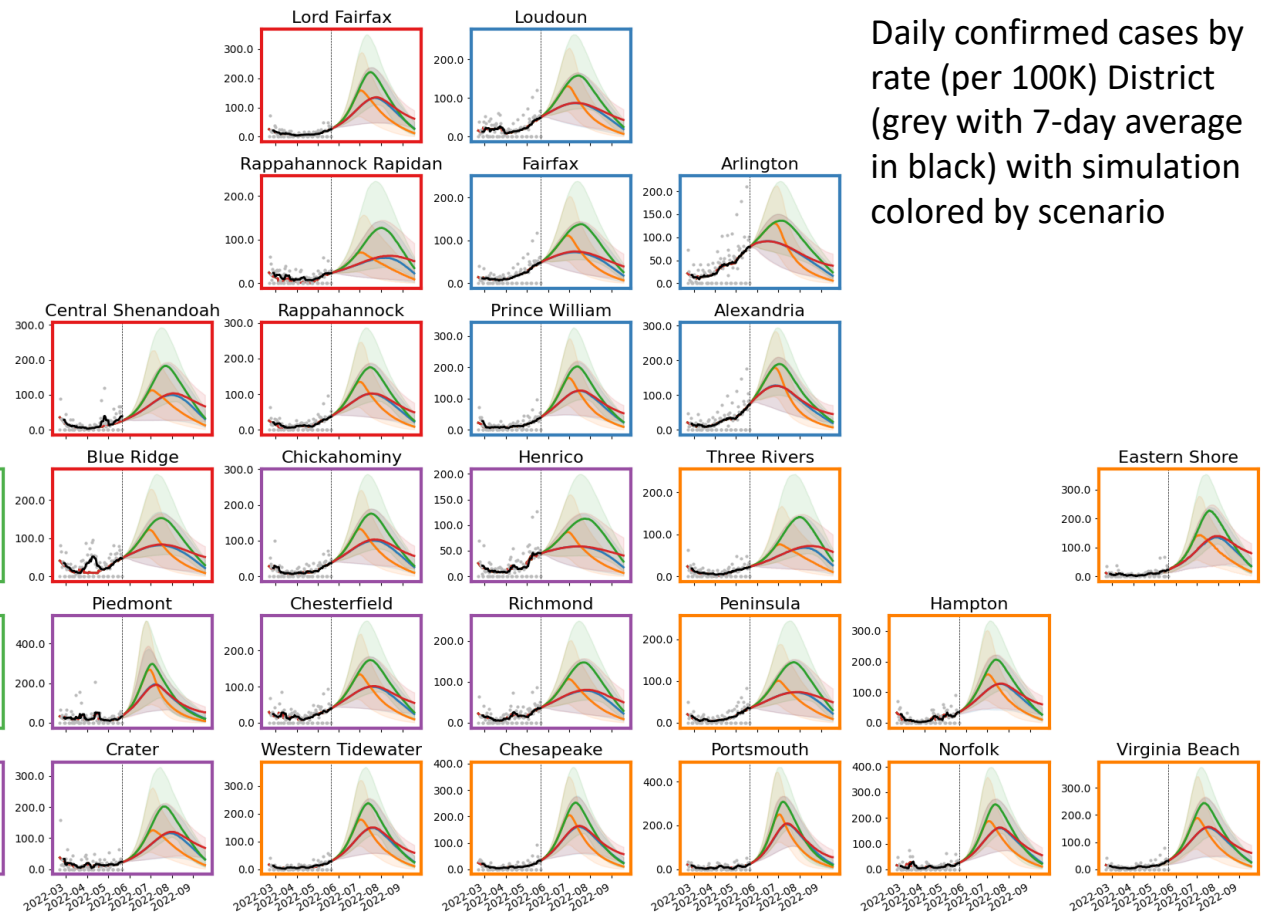
Daily confirmed cases)
by rate (per 100K)
District (grey with 7-day
average in black) with
simulation colored by
scenario

Detailed Projections: All Scenarios - Closer Look

Projections by Region



Projections by District



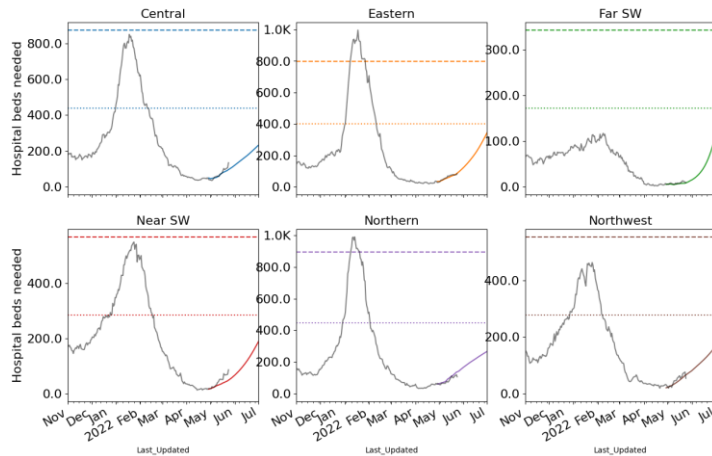
Daily confirmed cases by rate (per 100K) District (grey with 7-day average in black) with simulation colored by scenario

Hospital Demand and Bed Capacity by Region

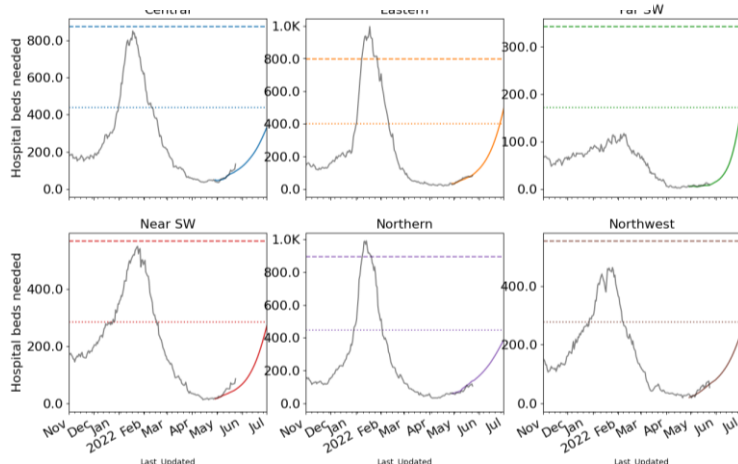
Capacities by Region

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds

Adaptive



Adaptive – Variant BA2_12



Length of Stay more variable with Omicron, occupancy projections may vary as a result, ad-hoc estimation performed per region

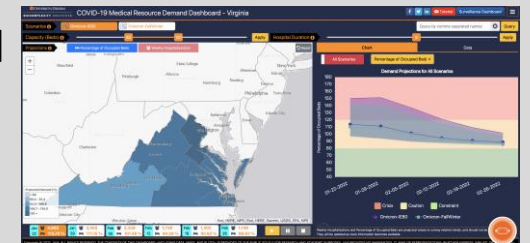
Estimated LOS shortened to better fit observed data

Projections show continued declines and with expanded capacities and adjusted length of stay, no capacities exceeded

Length of Stay Estimates

Central	6
Eastern	6
Far SW	6
Near SW	6
Northern	3
Northwestern	8

Interactive Dashboard
with regional
projections



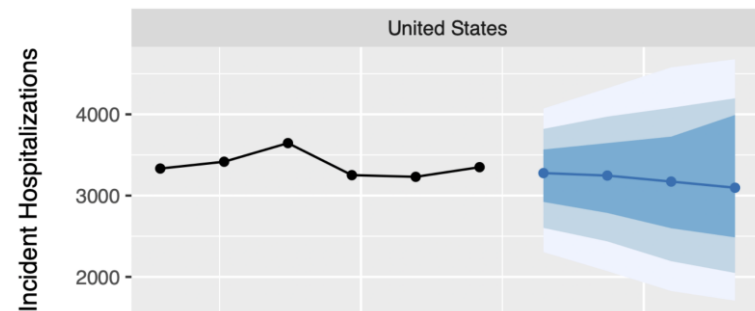
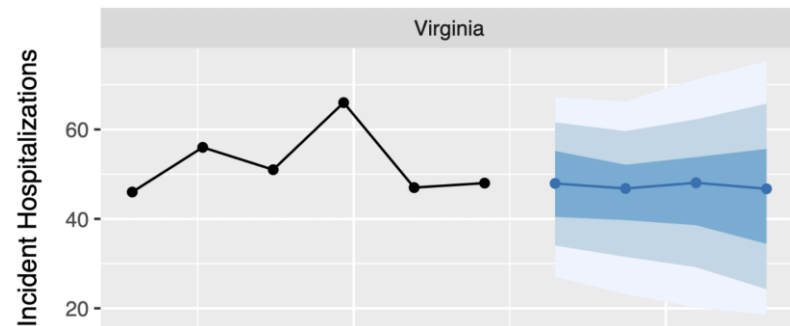
<https://nssac.bii.virginia.edu/covid-19/vmrddash/>

Current Influenza Hospitalization Forecast

Statistical models for submitting to CDC FluSight forecasting challenge

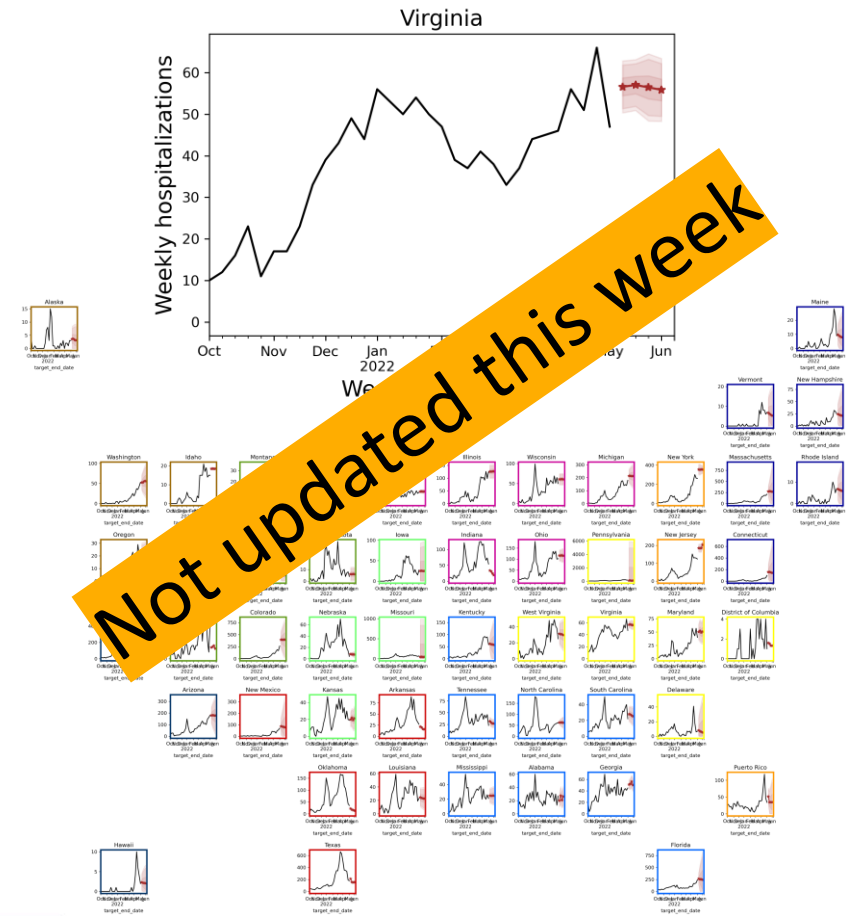
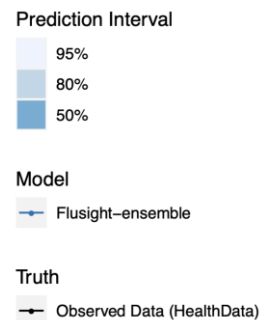
- Hospitalizations nationwide are rising, VA still steady

Hospital Admissions for Influenza and Forecast for next 4 weeks (UVA ensemble)



CDC FluSight

May 16th Ensemble Forecasts



Key Takeaways

Projecting future cases precisely is impossible and unnecessary.

Even without perfect projections, we can confidently draw conclusions:

- **Case rates continue to rise as do hospitalizations**
- VA 7-day mean daily case rate increased to 39/100K from 32/100K
 - US seems to be entering a plateau, down slightly to 33/100K from 36/100K
 - VA hospital occupancy (rolling 7 day mean of 441) has steadily rising for over a month
- Projections anticipate future growth in cases, with potential for growth to continue for several weeks:
 - VA continues to tracked BA.2.12.1 scenario from April 23rd projections closely
 - Rise in hospitalizations tracking cases pretty closely for past uncertainty surrounds impact of weather and changing social interactions
- Model updates:
 - Speculative BA.4 scenario added though parameterization contains a lot of uncertainty
 - Adaptive scenario BA.2.12.1 scenario to capture the future growth of this more transmissible variant
 - Models need to change their focused outcome to hospitalization or aggregate counties to districts to minimize noisy fluctuations

The situation continues to change. Models continue to be updated regularly.

Additional Analyses

Overview of relevant on-going studies

Other projects coordinated with CDC and VDH:

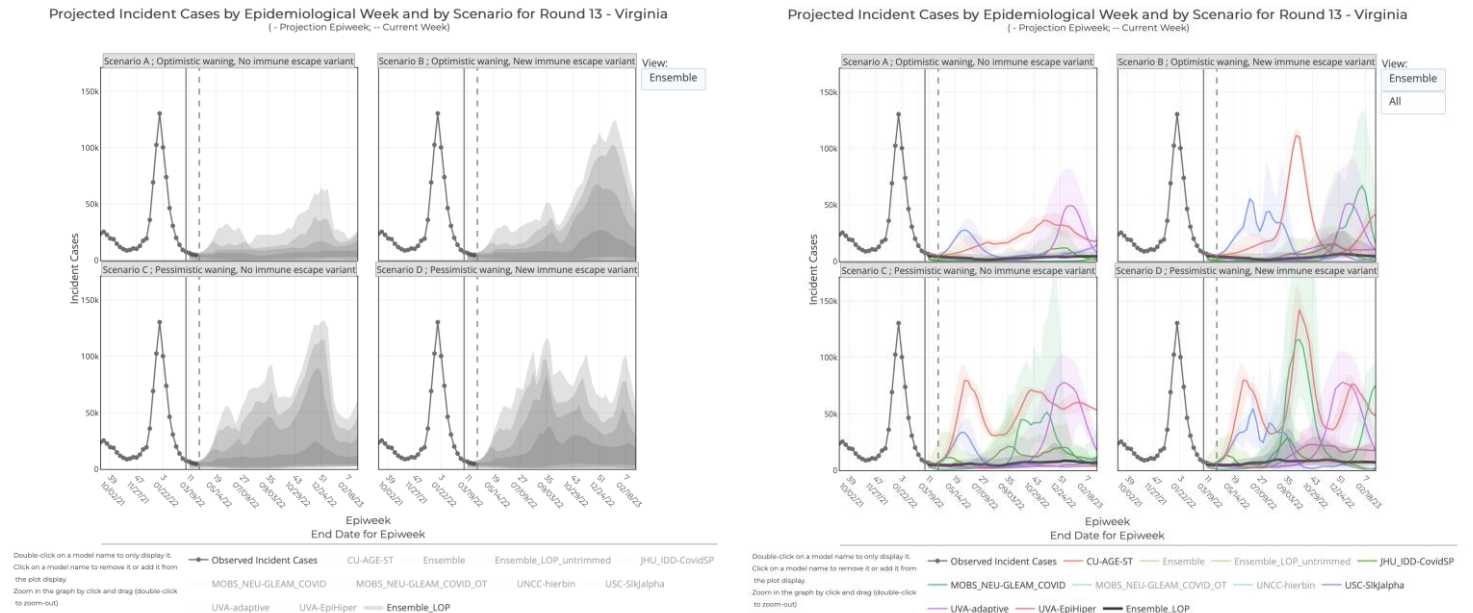
- **Scenario Modeling Hub:** Consortium of academic teams coordinated via MIDAS / CDC to that provides regular national projections based on timely scenarios
- **Genomic Surveillance:** Analyses of genomic sequencing data, VA surveillance data, and collaboration with VA DCLS to identify sample sizes needed to detect and track outbreaks driven by introduction of new variants etc.
- **Mobility Data driven Outreach locations:** Collaboration with VDH state and local, Stanford, and SafeGraph to leverage anonymized cell data to help identify sites most frequently visited by different demographic groups

COVID-19 Scenario Modeling Hub – Round 13

Collaboration of multiple academic teams to provide national and state-by-state level projections for 4 aligned scenarios

- Round 13 results getting finalized
 - Scenarios: New Variant in Summer and waning compared (yes/no new variant vs. 4 month or 10 month waning)
- Prelim results shared internally
- Only national consortium tracking Omicron wave well
- Rounds 4-12 now available
Round 4 Results were published May 5th, 2021 in [MMWR](#)

<https://covid19scenariomodelinghub.org/viz.html>



Busiest Places: Mobility Data Can Assist

SafeGraph provides fine-grained mobility measures

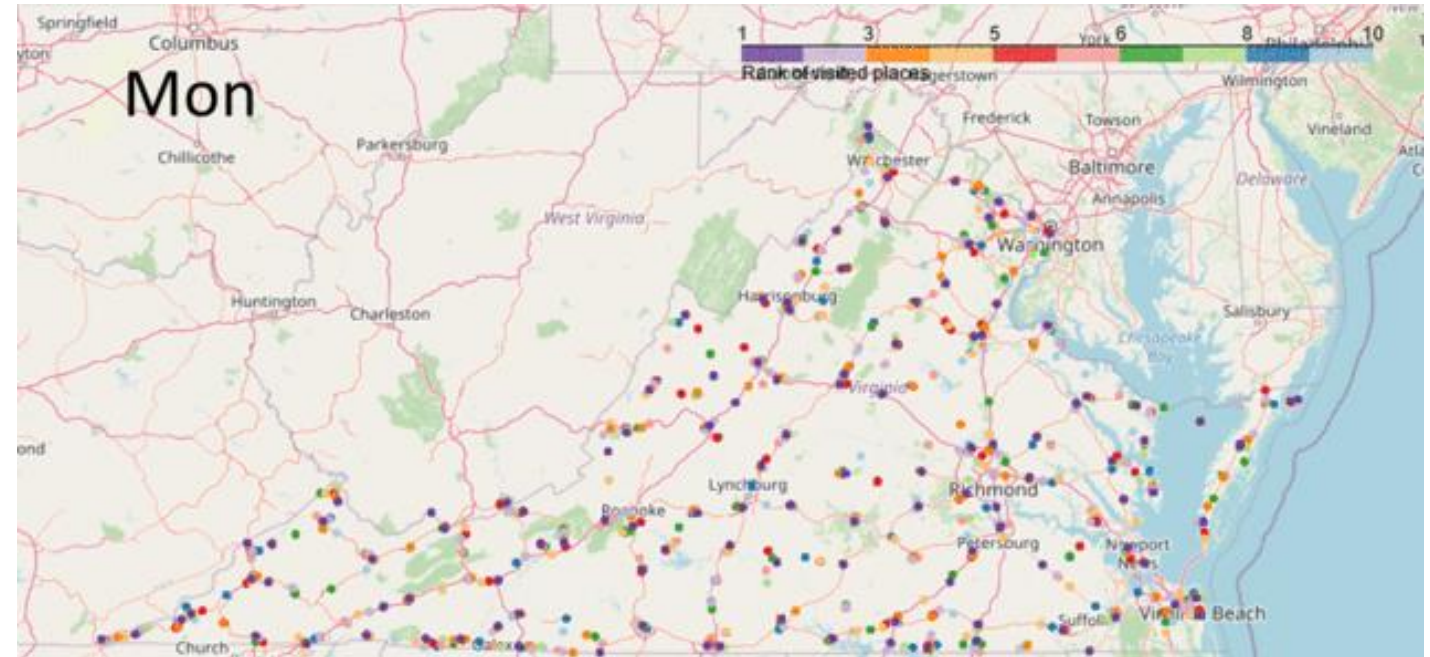
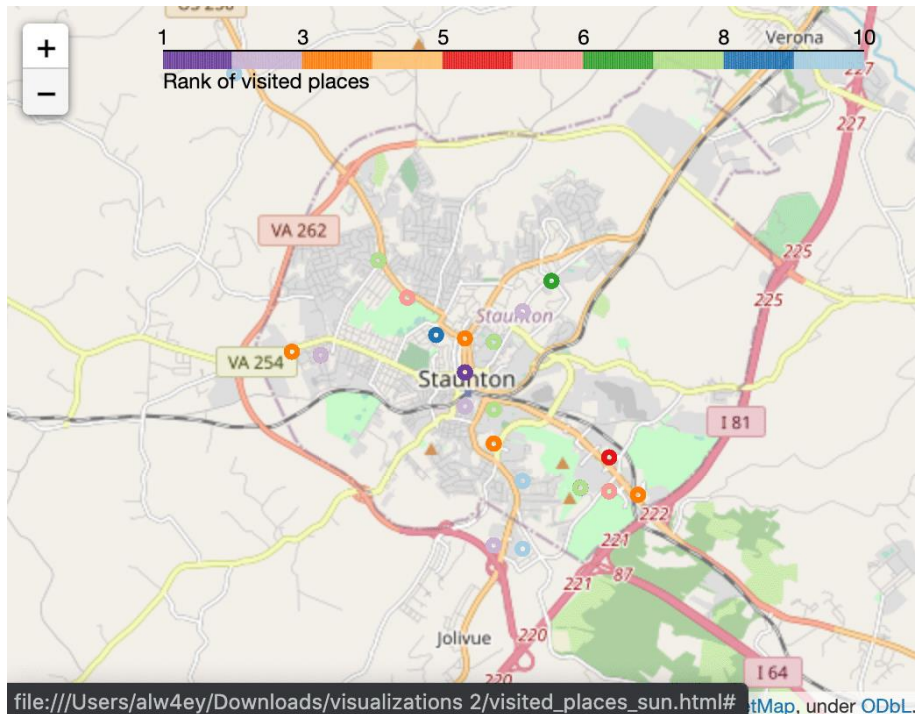
- [SafeGraph](#): anonymized geolocation data aggregated from numerous cell phone apps
- One of the most fine-grained and high-coverage mobility data sources available: 6.4 million POIs in the US; 158,869 POIs in VA
- Has been utilized by hundreds of researchers, governments, and the CDC to aid COVID-19 efforts (Chang, Pierson, Koh, et al., [Nature 2020](#); Chang et al, KDD 2021)
- Daily and hourly number of visits to points-of-interest (POIs), i.e., non-residential locations such as restaurants, bars, gas stations, malls, grocery stores, churches, etc.
- Weekly reports per POI of ***where visitors are coming from*** (at the census block group level)
- Still has [limitations](#) to be aware of (e.g., less representation among children and seniors)



SAFE GRAPH

Find the Busiest Locations

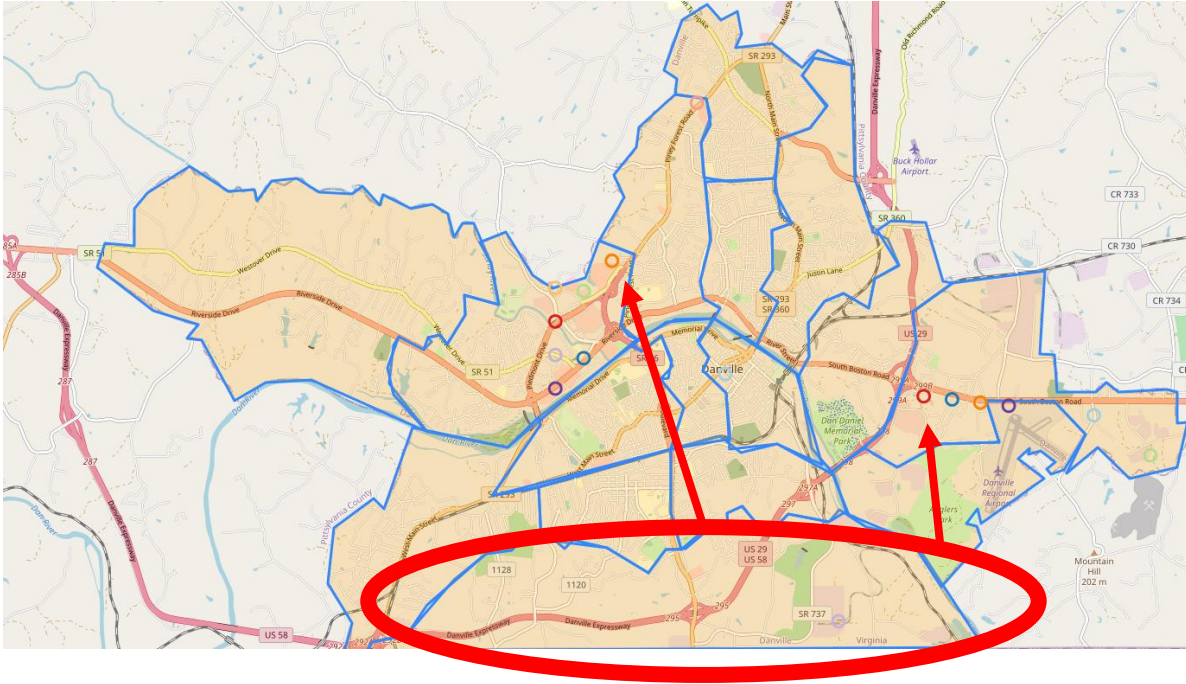
POIs are individual addresses,
need some aggregation to busy
areas



Busiest locations vary by day of week (and time of day)

Find locations visited by Target Population

Census Block Groups in Danville




1. Use census data to characterize the populations of the different census block groups
2. Identify most frequently visited POIs for each CBG
3. Cluster most visited POIs
4. Provide potential sites grouped by the demographic groups they likely serve

Goal: Provide frequently visited locations based on populations and vaccination levels one desires to reach

Example: List of locations in the Southside frequented by Black Virginians

Overview of the current roster of targeted populations

These are the current roster of targeted population groups that we are providing as part of the weekly delivery to VDH. (This roster is subject to change.)

- Whole population (eg, no target population filters are applied)
- Race Black
- Ethnicity Latinx
- Ages 20-40
- Ages 20-30
- Ages 30-40
- Unvaccinated populations
- Latinx or Black 

Data Elements in the CSV

HighlyVisitedAddress
This is the address of the POI in the L14 that sees the most visits. It is provided to make it easier to find the L14 on the map.

AreaMostVisitedPeriod
This is the 4-hour period in the week when the L14 sees its highest traffic. This is not target group-specific

NEW

Rank & LocationWeight
The LocationWeight is estimated # of visits to POIs in the L14 from the target group. Rank indicates the order from most- to 25th most-visited

Population Group
For a targeted file like this one, these will all be the same value.

AreaMostVisitedDay
This is the day of the week when most visitors go to this S2 location. This is not target group-specific.

Lat and Lon
This is the latitude and longitude for the center of the L14.

VDH District

S2 Key
(L14)

County

Locality	District	PopulationGroup	LocationID	Rank	LocationWeight	AreaMostVisitedDay	HighlyVisitedAddress	AreaMostVisitedPeriod	Lat	Lon
Accomack Co	Eastern Shore	Latinx or Black	89ba2b55	1	4966.030095	Friday	25297 Lankford Hwy Rt 13 N, C	Friday 17:00-21:00	37.6978738	-75.716796
Accomack Co	Eastern Shore	Latinx or Black	89ba2caf	2	3728.476605	Friday	26036 Lankford Hwy, Onley, VA	Friday 15:00-19:00	37.6881681	-75.722612
Accomack Co	Eastern Shore	Latinx or Black	89ba2b57	3	3508.193676	Saturday	25274 Lankford Hwy, Onley, VA	Saturday 13:00-17:00	37.69859	-75.722612
Accomack Co	Eastern Shore	Latinx or Black	89bbd4ad	4	2582.802769	Wednesday	25102 Lankford Hwy, Onley, VA	Sunday 11:00-15:00	37.7023677	-75.710981
Accomack Co	Eastern Shore	Latinx or Black	89ba2b53	5	1844.868961	Sunday	25102 Lankford Hwy, Onley, VA	Friday 16:00-20:00	37.7030842	-75.716796
Albemarle Co	Blue Ridge	Latinx or Black	89b38647	1	14088.0684	Thursday	1215 Lee St, University of Virg	Thursday 07:00-11:00	38.0327733	-78.500766
Albemarle Co	Blue Ridge	Latinx or Black	89b477ff	2	6999.363545	Saturday	1980 Rio Hill Ctr, Charlottesville	Saturday 12:00-16:00	38.087391	-78.472353
Albemarle Co	Blue Ridge	Latinx or Black	89b38645	3	5824.383454	Wednesday	Cabell Hall 525 McCormick Roa	Wednesday 11:00-15:00	38.033334	-78.506447
Albemarle Co	Blue Ridge	Latinx or Black	89b3888d	4	5078.488029	Friday	540 Pantops Ctr, Pantops, VA,	Thursday 11:00-15:00	38.0334982	-78.455301
Albemarle Co	Blue Ridge	Latinx or Black	89b387fd	5	4655.844131	Saturday	100 Twentyninth Place Ct, Cha	Saturday 11:00-15:00	38.077516	-78.478036

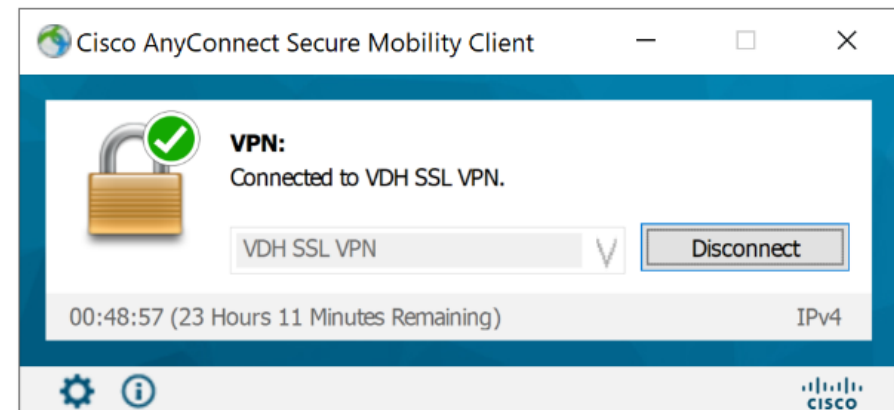
Mobility Data Updated Weekly

Box: <https://virginia.box.com/s/03kq8el0kzd9w43wz2g3myozov76uizo>

- Excel sheets and simple HTML maps packaged for use

VDH has a dashboard available upon request to allow interactive viewing

- <https://arcgis.vdh.virginia.gov/portal/apps/opsdashboard/index.html#/8631cfc4f181460fafc7e1923f41d581>
- Dashboard is restricted to VDH offices and those who VPN into the CoV Network



References

Venkatramanan, S., et al. "Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints." *PLoS Computational Biology* 15.9 (2019): e1007111.

Arindam Fadikar, Dave Higdon, Jiangzhuo Chen, Bryan Lewis, Srinivasan Venkatramanan, and Madhav Marathe. Calibrating a stochastic, agent-based model using quantile-based emulation. *SIAM/ASA Journal on Uncertainty Quantification*, 6(4):1685–1706, 2018.

Adiga, Aniruddha, Srinivasan Venkatramanan, Akhil Peddireddy, et al. "Evaluating the impact of international airline suspensions on COVID-19 direct importation risk." *medRxiv* (2020)

NSSAC. PatchSim: Code for simulating the metapopulation SEIR model. <https://github.com/NSSAC/PatchSim>

Virginia Department of Health. COVID-19 in Virginia. <http://www.vdh.virginia.gov/coronavirus/>

Biocomplexity Institute. COVID-19 Surveillance Dashboard. <https://nssac.bii.virginia.edu/covid-19/dashboard/>

Google. COVID-19 community mobility reports. <https://www.google.com/covid19/mobility/>

Biocomplexity page for data and other resources related to COVID-19: <https://covid19.biocomplexity.virginia.edu/>

Questions?

Points of Contact

Bryan Lewis
brylew@virginia.edu

Srini Venkatramanan
srini@virginia.edu

Madhav Marathe
marathe@virginia.edu

Chris Barrett
ChrisBarrett@virginia.edu

Biocomplexity COVID-19 Response Team

Aniruddha Adiga, Abhijin Adiga, Hannah Baek, Chris Barrett, Golda Barrow, Richard Beckman, Parantapa Bhattacharya, Jiangzhuo Chen, Clark Cucinell, Patrick Corbett, Allan Dickerman, Stephen Eubank, Stefan Hoops, Ben Hurt, Ron Kenyon, Brian Klahn, Bryan Lewis, Dustin Machi, Chunhong Mao, Achla Marathe, Madhav Marathe, Henning Mortveit, Mark Orr, Joseph Outten, Akhil Peddireddy, Przemyslaw Porebski, Erin Raymond, Jose Bayoan Santiago Calderon, James Schlitt, Samarth Swarup, Alex Telionis, Srinivasan Venkatramanan, Anil Vullikanti, James Walke, Andrew Warren, Amanda Wilson, Dawen Xie